ARI Research Note 92-14

AD-A247 002

Building Human Variables Into Combat Models

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January 1992

United States Army
Research Institute for the Behavioral and Social Sciences

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS --
2a. SECURITY CLASSIFICATION AUTHORITY -- 2b. DECLASSIFICATION/DOWNGRADING SCHEDULE --	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
4. PERFORMING ORGANIZATION REPORT NUMBER(S) VRI-ARI-9 FR89-1(R) Vol. II	5. MONITORING ORGANIZATION REPORT NUMBER(S) ARI Research Note 92-14
6a. NAME OF PERFORMING ORGANIZATION Vector Research, Incorporated 6b. OFFICE SYMBOL (If applicable) --	7a. NAME OF MONITORING ORGANIZATION U.S. Army Research Institute Manned Systems Group
6c. ADDRESS (City, State, and ZIP Code) P.O. Box 1506 Ann Arbor, MI	7b. ADDRESS (City, State, and ZIP Code) 5001 Eisenhower Avenue Alexandria, VA 22333-5600
8a. NAME OF FUNDING/SPONSORING ORGANIZATION U.S. Army Research Institute for the Behavioral and Social Sciences 8b. OFFICE SYMBOL (If applicable) PERI-S	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER MDA903-86-C-0428
8c. ADDRESS (City, State, and ZIP Code) 5001 Eisenhower Avenue Alexandria, VA 22333-5600	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. 62785A PROJECT NO. 791 TASK NO. 353 WORK UNIT ACCESSION NO. C01

11. TITLE (Include Security Classification)
Building Human Variables Into Combat Models

12. PERSONAL AUTHOR(S)
Cherry, W. Peter; Davis, Reed E.; and Brecht-Clark, Jan

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM 86/09 TO 88/12	1992, January	104

16. SUPPLEMENTARY NOTATION
Horizons Technology, Inc., is a subcontractor of Vector Research, Inc.
David Promisel, Contracting Officer's Representative

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Human performance, Combat models, Continuous operations, Sustained operations, Fatigue, Training

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report presents a conceptual framework designed to represent human factors in combat models. The framework is organized to focus on small teams of "executing elements," the baseline performance of those teams in delivering their increment of combat power, and changes in performance associated with stress/recovery processes. The framework served as a starting point for research carried out at the National Training Center that investigated the impact of fatigue on combat performance. With respect to this goal, the results were largely inconclusive. However, the results did support a series of hypotheses that focused on the performance of command control executing elements and the high dependency between this performance and combat outcomes.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL David Promisel	22b. TELEPHONE (Include Area Code) (703) 274-6917 22c. OFFICE SYMBOL PERI-SM

DD Form 1473, JUN 86 Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency Under the Jurisdiction of the Deputy Chief of Staff for Personnel

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Research accomplished under contract for the Department of the Army

Vector Research, Inc.

Technical review by

Howard H. McFann

Accesion For		
NTIS CRA&I		✓
DTIC TAB		☐
Unannounced		☐
Justification		
By		
Distribution /		
Availability Codes		
Dist	Avail and / or Special	
A-1		

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BUILDING HUMAN VARIABLES INTO COMBAT MODELS

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INTRODUCTION

Background

This report describes the results of research performed for the US Army Institute for the Behavioral and Social Sciences (USARI) under the terms of contract number MDA903-86-C-0248. The research, entitled **Building Human Variables into Combat Models**, was performed by a team led by Vector Research, Incorporated (VRI) as prime contractor, with Horizons Technology, Incorporated (HTI) and Essex Corporation as subcontractors. The research was initiated in September 1986. Dr. David M. Promisel of USARI Systems Research Laboratory was the Contracting Officers Technical Representative (COTR). Dr. Irving Alderman served as deputy COTR and made significant contributions to the research directions and the research itself.

The objectives of the research associated with "Building Human Variables into Combat Models" derived from perceived shortcomings of the combat models and analyses performed in support of Army decision making and from the expectations that "soldiers on future battlefields will experience: high lethality, high disability, high stress, significant casualties in rear areas, severe sleep deprivation, low light levels, and operations during normal sleeping hours."[1] The technical objectives as provided in the Statement of Work were "to identify human variables that are expected to influence predictions of combat effectiveness, to develop procedures for measuring these variables and collecting data, and then to estimate the nature and level of their effects." Research performed by the team to accomplish these objectives is summarized in the remainder of this introduction and described in greater detail in the body of the report.

Approach

Two principal tasks were included in the research program. The first task was to develop a conceptual framework "for inquiry identifying the range of variables to be examined and the types of hypotheses to be investigated." This development required that the following factors be addressed:

1. level of detail (e.g., global versus mission versus task-specific);

2. scope (e.g., type of terrain and/or mission, nature of enemy threat); and

3. anticipated complexity (e.g., simple "decrement" factors to adjust soldier performance under specified conditions such as fatigue

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[1]DePuy, William, "Concepts of Operation: The Heart of Command, The Tool of Doctrine", Army, August 1988, pp. 26-40.

versus more complex sets of relationships with multiple interacting variables.

The development of a preliminary version of the conceptual framework was the first subtask in the research program.[2] It was based upon review of material from three sources: (1) a subject matter expert with extensive experience in combat, in training, and in command; (2) anecdotal accounts of battle, including autobiographical and biographical literature and military history; and (3) the behavioral science literature. The development also drew on the experience of the research team with the National Training Center (NTC) and with combat modeling and analysis.

The review of the behavioral science literature constituted the second subtask, and it was given a particular focus and scope, namely, it was restricted to material related to fatigue and its role in combat. This approach was adopted for a number of reasons. First, the nature of combat envisioned by AirLand Battle Future involves continuous, high stress operations and understanding fatigue is very important. Second, a series of experiments involving fatigue were scheduled to occur during the period of the contract, and it was hoped that these experiments could be utilized in a serendipitous manner.

The literature on fatigue and related stressors likely to be encountered in the battlefield is enormous, but much of it is not helpful from the viewpoint of performance problems posed by continuous operations. To constrain the literature search, which included the data bases of the Defense Technical Information Center (DTIC), and the National Technical Information Service (NTIS), we employed a strategy that required report titles to include not only key terms such as fatigue and/or stress, but also performance. Special searches were also conducted on "human variables in combat", "combat fatigue", and "combat stress". These initial searches, plus a sizable reference list of our own on fatigue and other stressors, created a large inventory of possibly relevant articles and technical reports. Titles and abstracts were then thoroughly screened for apparent relevance to long term performance, loss of sleep, and other stressors likely to be encountered in a combat environment (e.g., heat, noise, vibration, enemy action). This search procedure was generally followed until the reference lists of newly acquired documents showed a high degree of overlap with those previously acquired.

Data bases of DTIC and NTIS, as well as MedLine were searched for studies involving physical fatigue and related stressors. Relevant areas in this search included physiology, muscle strength, endurance, and rest and recovery periods. While reports of studies involving continuous operations and physical work from the military community were preferred, relevant industrial or laboratory studies involving repetitive manual materials handling, heavy physical work, physical work capacity, and heat stress were also considered.

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[2] Evans, S.M., Mackie, R.R. and Wylie, D.D. "Fatigue Effects on Human Performance in Combat: A Literature Review". (ARI Research Note). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (In process)

The third and final subtask was to refine the preliminary conceptual framework. This subtask was originally intended to be based on "findings from the literature review and input from recognized military/research authorities". Both these sources were used, however, results of research performed at NTC also played a significant role in determining the final form of the framework.

The second principal task of the research program was the estimation of the effects of specified human variables on the combat process. It included the development of testable models and hypotheses, preparation of a research plan, development of data collection instruments and procedures, implementation of the research plan, and synthesis of the research findings. These five subtasks were completed in the context of a particular rotation at NTC and focused on the impact of sleep-loss and fatigue on combat effectiveness.

The rationale for choosing an NTC rotation as a research vehicle was related to an opportunity to "piggyback" on other research scheduled well before the initiation of this study. For the rotation in question, the Walter Reed Army Institute of Research (WRAIR) had instrumented 68 soldiers (primarily members of the battalion staffs, the company, and the platoon leaders) with wrist monitors which measured activity as a function of time over the 14 days of the rotation. For the same rotation, the Leadership and Management Technical Area of the USARI Training Laboratory conducted research on platoon leadership. It was the opinion of the research team that, if the NTC digital data base, After Action Reviews (AAR), and Take Home Packages (THP) could be analyzed, that an understanding of the link between fatigue, leadership, and battalion effectiveness might be developed. Accordingly, research plans were prepared to investigate the link between fatigue and platoon leadership using WRAIR and Leadership and Management Technical Area results[3] and to investigate the links between fatigue and combat effectiveness using WRAIR data, Leadership and Management Technical Area data, and digital data, AAR, and THP from NTC.[4]

HTI examined the observer controller and subject matter expert data and the WRAIR sleep data to assess if there was a tie between sleep patterns/levels and the subjectively rated unit performance. HTI also examined pre- and post-rotation questionnaires and the resulting data on leadership, attitudes, commitment, morale, training adequacy, training quality, and demographics on military and unit history and responsibilities to assess possible relationships between sleep patterns and experience, longevity in the unit, and unit leadership ratings.

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[3]Horizons Technology, Incorporated (1987). Research Plan for Examining the Effects of Sleep Loss on Leadership and Unit Performance at the NTC. Oakton, VA: Horizons Technology, Incorporated.

[4]Davis, R. (May, 1988). NTC Data Base Analysis (VRI-ARI-9 WN88-1(R)). Ann Arbor, MI: Vector Research, Incorporated.

The approach proposed for the analysis of NTC data centered on the concept of minibattles, derived from Rowland,[5] and synchronization[6] both consistent with the early versions of the conceptual framework. Synchronization provided a basis for investigating a series of hypotheses. The research plan focused on the digital data base but included analysis of AAR and THP. It also included participation by TRADOC Analysis Command, White Sands Missile Range (TRAC-WSMR), as a source of terrain and line-of-sight analyses.

Research Results

The results of the research program fall into two categories. The first category encompasses the conceptual framework and the associated literature review. The second category includes the hypotheses and models derived from the conceptual framework and the research carried out on the NTC rotation. The results are summarized as follows.

Conceptual Framework. The conceptual framework has two principal components. The first embodies a perspective of combat which views the combat process as resulting from the activities of small units, groups, or teams -- the executing elements of vertical functional systems or battlefield operating systems. Two types of small units, groups, or teams are included: one that is an executing element and one that provides command and control -- both vertical and horizontal. The framework thus addresses all levels of combat from squad to theater and emphasizes both performance of tasks and missions and the degree to which synchronization is present among different elements of a vertical functional system and between elements of different vertical functional systems. This choice of "level of resolution" is based upon a requirement to represent the fact that not all subunits of, for example, battalion, brigade, or division, are equally capable or at any given time equally influenced by human variables. It also reflects an approach to determining combat effectiveness that emphasizes synchronization.

Given a particular small unit, group, or team, the impact of human variables on its performance of tasks or a set of tasks and its behavior is addressed in the second component of the framework, which is in a mathematical sense a set of conditioning arguments or implicit functions describing changes in performance and behavior over time. The first "function"

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[5]Rowland, D. (June, 1986). "Assessment of Combat Degradation". RUSI Journal, 33-43.

[6]DePuy, W. (January, 1988). "Baseline Functional, Organizational, and Procedural Structure for the Command and Control of an AirLand Battle Force in a Joint Environment". Briefing to Commander, Combined Arms Center. both consistent with the early versions of the conceptual framework. Synchronization provided a basis for investigating a series of hypotheses. The research plan focused on the digital data base but included analysis of AAR and THP. It also included participation by TRADOC Analysis Command, White Sands Missile Range (TRAC-WSMR), as a source of terrain and line of sight analyses.

reflects that performance, measured in terms of task or behavior selected, and time, accuracy, and completeness of task performance, has a baseline that is a function of basic abilities, individual and collective training, cohesion and leadership, and supervision (by an internal leader). The second "function" addresses environmental stressors and postulates that exposure to these stressors together with the intensity of task performance causes changes in baseline performance. The third "function" deals with the stress-recovery process and relates changes in performance for a given set of environmental stressors to the nature of the stress-recovery process. The final "function" deals with so-called intangible factors -- morale, motivation, and leadership and is based on an assumption that these factors primarily influence performance by changing the impact of the stress-recovery process.

The conceptual framework leads to a concept for addressing human variables that involves decrement factors to be derived from the four functional forms described above, related to time. It also implies that in order to address issues of unit or formation effectiveness relative to human variables, analysts and researchers must represent the distribution of positions in stress-recovery cycles over the different executing elements and vertical functional systems.

Literature Review. The literature review served two purposes. The first was to provide insights to the development of the conceptual framework; the second was to ascertain the degree to which the literature could be used as a source of data to describe the impact of human variables in combat. As noted above, the literature review focused on fatigue and sleep-loss. In this context it supported the emphasis in the framework on the stress-recovery process and on the categorization into small units, groups, or teams. In terms of serving as a source of data, however, the review was not as useful as had been hoped.

Much of the literature concerning the effects of fatigue on human performance, including studies where military type tasks were performed as well as those employing fundamental psychological tests, have been inconclusive because of improper experimental protocol, the nature and duration of the tasks studies, and the type of test device used and when administered. Many studies do not report a baseline of performance, making it difficult to describe the effects of fatigue on performance in quantitative terms. In addition, there is very little information on the combined effects of fatigue and other battle related stressors, such as heat, cold, vibration, confinement, and noise, as well as real world adverse environments and uncertainties.

In addition to examining the behavioral science literature, anecdotal material was reviewed. The anecdotal literature is a means of establishing human behavior in combat and is useful in this regard. However, because it deals with specific combat situations it does not provide the range of situations nor the degree of control necessary to develop quantitative data regarding human variables and performance.

NTC Research

The research performed in conjunction with WRAIR and the Leadership and Management Technical Area of USARI had as its objective linking fatigue and sleep-loss to combat effectiveness through small unit leadership and battalion command and control. The results, compared to this objective, are at best ambiguous. First, not all the units had instrumented personnel. Second, for those personnel for whom data were available, it is not clear that the rest-activity patterns realized are consistent with the build-up of fatigue. Given that there is no firm evidence of fatigue, other causes must be sought to explain the combat results and unit effectiveness. In itself this proved to be useful.

The analysis of combat dynamics and unit effectiveness using the digital data base, AAR, and THP was designed to address four hypotheses:

(1) a small unit's performance in delivering its "increment" of combat power is dominated by initial conditions which determine opportunities to participate;

(2) determination of initial conditions is dominated by leadership and supervision;

(3) given opportunities to participate, the level of participation by individual systems does not vary significantly; and

(4) given a decision to participate, soldier/system contribution does not vary significantly.

The quality of the digital data base precluded extensive analysis at the level of detail originally proposed. Nonetheless, the evidence developed provides no reason to reject any of the four hypotheses. Individual system performance was shown to be at or beyond standards in such tasks as engagements. The data suggested that a fraction of systems do not participate even when given opportunities. Leadership and supervision were key to ensuring that tasks were initiated, in particular, engagement and synchronization across vertical functional systems. NTC results also provided examples of the extreme realization of hypothesis one -- units failed to contribute or contributed only marginally because they were in the wrong place at the wrong time due to command and control deficiencies.

To supplement the quantitative analysis (which relied heavily on the digital data base), a qualitative analysis of a small set of randomly chosen AAR and THP was undertaken. This analysis focused on occurrences of events which indicated failures to synchronize among the executing elements of different vertical functional systems. While the training role of NTC cannot be ignored, the analysis revealed consistent patterns of breakdowns in synchronization and suggested that the NTC data could serve as a source of baseline data for the performance of command and control elements at levels above platoon. It is this "executing control element" that is the major determinant of unit effectiveness in the rotations examined in this research.

CONCEPTUAL FRAMEWORK

As noted in the introduction, the first task of this study was to develop a conceptual framework "for inquiry identifying the range of variables to be examined and the types of hypotheses to be investigated". Three subtasks were required: the development of a preliminary framework, a synthesis of relevant literature, and refinement of the framework based upon the results of the literature review and "input from recognized military/ research authorities". The approach taken to complete this task and its results are described in this chapter.

Approach

In order to develop a conceptual framework for inquiry into human variables in combat it was first necessary to adopt a description of the combat process to identify key events and processes in combat and the role of soldiers in those events and processes. That description then served as a basis for examining human variables and their impact on process dynamics and outcomes. The examination of human variables was restricted initially to fatigue, because of the interest in Continuity of Operations (CONOPS), and because of an opportunity to utilize planned research at the National Training Center. (This research involved measurement of sleep/activity cycles by researchers from the Walter Reed Army Institute of Research (WRAIR) and investigation of relationships between sleep loss and leadership by researchers from the Leadership and Management Technical Area of the Training Research Laboratory of ARI.) The literature review thus concentrated primarily on the effects of sleep loss as reported in the behavioral science literature. It included a review of selected autobiographical material and was supported by discussions with military experts. The last step in the development of the conceptual framework was the incorporation of revisions based upon observations and results obtained using the NTC data base, after action reviews, and take home packages.

Considerations in Developing the Preliminary Conceptual Framework

A Structure for the Combat Process. The structure proposed to describe the combat process is based upon constructs used by General William E. Depuy (US Army, Retired). As illustrated in figure 1, the first component of this construct defines the basic functional systems which operate in combat. These "vertical functional systems" are organizational systems which possess their own command and control subsystems at levels ranging from squad or team to corps and echelons above corps. Key to the purpose at hand, namely, inquiry into human variables, is the fact that the contribution of the vertical functional systems is made by executing elements that are small units or teams. Also key is the fact that the marginal value of the contribution of any executing element is enhanced or degraded by the degree to which it is synchronized by the horizontal systems: command and control at each echelon. In this regard, DePuy has described outputs of the command and control processes as:

- developing nested concepts of operation;
- specifying task organization;

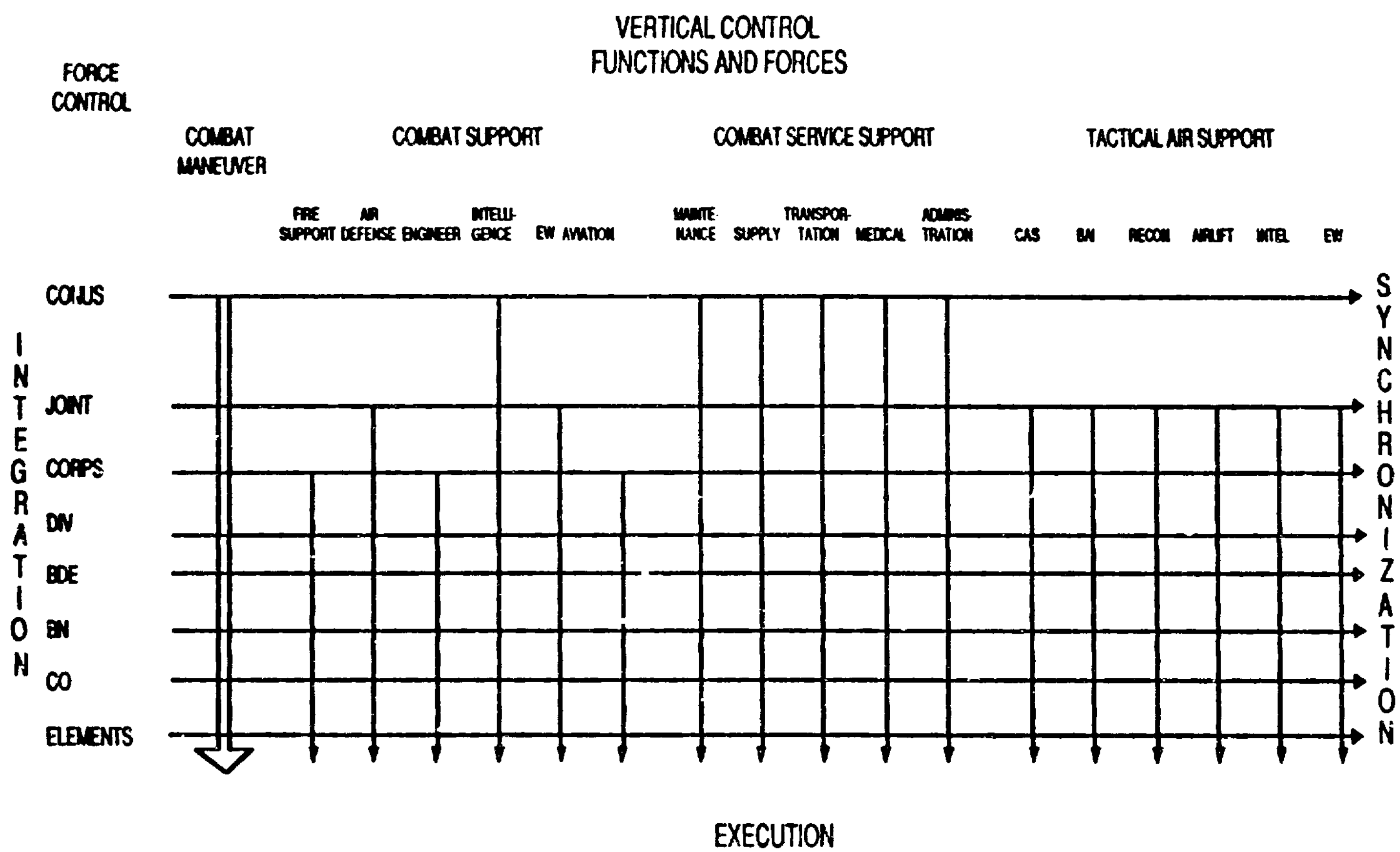

FIGURE 1. TACTICAL SYNCHRONIZATION THE C^2 MATRIX

- specifying or clarifying command relationships;
- establishing cross-service procedures and organization;
- directing tactical synchronization of combat support, combat service support, and cross-services functions with maneuver;
- conducting corps collateral campaigns;
- harmonizing major campaigns; and
- conducting joint collateral operations.

Clearly, this description encompasses combat at levels from squad to theater, and it includes tactical and operational command and control. In the context of a preliminary conceptual framework it suggested:

- consideration must be given to "executing elements", i.e., small units or teams;
- synchronization is a critical process which has a major impact on the "increment of combat power" delivered by executing elements; and
- synchronization is a product of command and control; command and control is accomplished by small groups analogous to executing elements.

Inferred from these three observations were three requirements for the framework:

- the framework must focus attention on the performance of small units and groups, i.e., the delivery of increments of combat power;
- the framework must accommodate the impact of command and control within executing elements, i.e., vertical functional system; and
- the framework must reflect the command and control of executing elements, i.e., horizontal integration.

This initial perspective is not inconsistent with other descriptions of combat and combat forces. The vertical functional systems are analogous (but not identical) to the Battlefield Operating Systems of the Blueprint of the Battlefield[7] and to the functional description utilized by Cherry, et al.,[8] in the design of the Theater Force Effectiveness Combat Simulation (TFECS). The focus on small groups is consistent with such authors as

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[7]TRADOC. Blueprint of the Battlefield. TRADOC-PAM 11-9.

[8]Cherry, W.P. (1977). **Theater Force Evaluation by Combat Simulation, Volume I: Process Descriptions** (VRI-CAA-2 FR77-1). Ann Arbor, MI: Vector Research, Incorporated.

Marshall[9] and Kellett,[10] as is the emphasis on command and control and leadership. The perspective leads to a definition of the combat process as follows: combat is the interaction of two or more forces consisting of activities performed by small groups or units separated in space and time. Ideally the activities of these small units or groups are coordinated and synchronized by the command and control of the vertical functional system to which they belong and by the horizontal integration of command and control at the echelons to which they belong and at those echelons above them.

Human Performance. Irrespective of vertical functional system and associated tasks, individual soldiers can be characterized in terms of anthropometric variables and in terms of basic abilities, such as:

- vigilance -- an individual's ability to detect signals of varying frequencies during activities involving continual visual or auditory watch;
- reaction time -- the elapsed time period between the presentation of stimulus and the onset of the behavioral response (usually motor or verbal);
- perception -- the process for interpreting sensations; and the sensory awareness of external objects, qualities, or relations;
- cognition -- all the processes by which sensory input is transformed, reduced, elaborated, stored, recovered, and used. Cognition may also operate in the absence of external stimulation, as in internally produced reasoning, decision making, and problem solving;
- memory -- the capacity to hold a stimulus or information either temporarily, in sensory or short term memory, or permanently, in long-term memory;
- perceptual-motor -- movements in response to a nonverbal stimulus, such as tracking targets. The response is determined by sensory input organized by the operator;
- psychomotor capabilities -- the action of a muscle resulting directly from a mental process. The mental process may be triggered by sensory inputs, such as incoming messages; and
- physiological capacity -- the response and adaptation of the body to external stressors, such as heat, force, vibration, etc.

These basic abilities, modified by training and knowledge, combine with workspace or soldier-system interface design to establish baseline task performance. In the context of small unit or small group performance, cohesion and collective training are further factors that must be included in establishing baseline collective task performance which leads to incre-

[9]Marshall, S.L.A. (1978). Men against Fire. Gloucester, MA: Peter Smith.

[10]Kellett, A. (1980). Combat Motivation (ORAE Report No. R77). Ottawa, Canada: Operational Research and Analysis Establishment.

ments of combat power. For both individual soldiers and the small units or groups to which they belong, measurement of task or task sequence performance in a classic sense, i.e., timeliness, accuracy, and completeness, is one part of investigating combat effectiveness and the role of human variables. A second and perhaps equally important part is related to behavior and the process (conscious or not) of a behavior in response to a stimulus. Marshall[11] reported on the number of infantrymen who participated in firefights, and Rowland[12] has examined levels of participation in combat, field trials, and simulations. Witus,[13] in an analysis based upon Kahlny[14], provides examples of behaviors that are not consistent with training (e.g., suppression by artillery fires), and DePuy[15] points out instances of the failure of soldiers and small units to initiate tasks or complete tasks as a result of stress arising from various sources. This suggests that it is important to include within the conceptual framework not only consideration of baseline task performance, but also consideration of task or behavior selection. In the baseline consideration of the latter is most strongly related to training and knowledge, i.e., preparation, motivation, and small unit leadership and supervision.

Environmental Stressors. In order for the conceptual framework to provide for variations in task performance and thus contribution to combat, it must include factors which reflect the conditions under which tasks are performed. These include:

1. thermal environment -- defined by the temperature, humidity, and air flow. Operating in cold environments can be prolonged with appropriate protective clothing, but possibly at the expense of reduced mobility. Heat acclimatization and increased fluid intake can delay the onset of heat stress in hot environments;

2. mechanical environment -- vibration or g-forces produced by the inherent characteristics of the system (e.g., engine vibration), or due to the operational mission (terrain, flight maneuvers). Local biodynamic (e.g., grip pressure), psychomotor, and speech intelligibility performance decrements occur with increased vibration;

3. auditory environment -- present as a combination of wanted sounds of messages, and auditory warnings, unwanted noise due to irrelevant messages on communications, radio static, engine noise,

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[11]Marshall, S.L.A. (1978).

[12]Rowland, David. (June, 1986). "Assessment of Combat Degradation" RUSI JOURNAL. pp 33-43.

[13]Witus, G. (1987). **Illustration of an Approach to Refine the Preliminary Conceptual Framework Using Historical Evidence of Human Variables in Combat.** (VRI-ARI-9 WP87-1). Ann Arbor: Vector Research, Inc.

[14]Kahlny, A. (1984). The Heights of Courage: A Tank Leader's War in the Golan. Westport, CN: Greenwood Press.

[15]DePuy, W. (1987). The Effects of Fatigue on Individual and Unit Performance (VRI-ARI-9 WN87-1). Ann Arbor: Vector Research, Inc.

explosions, gun fire. Increasing noise levels inhibit performance on prescribed auditory tasks, and at extreme levels, also inhibit visual and physiological performance;

4. visual environment -- defined by the level of task (e.g., spot lighting) and overall (e.g., day versus night) illumination, contrast, glare intensity, visual obscuration, such as smoke, fog, or haze, and limited field of view. In general, increased glare or obscuration decrease performance, while increased illumination and contrast up to specified levels increase performance;

5. toxic environment -- present as airborne pollutants, existing due to inadequate ventilation of the operating system (e.g., carbon monoxide, etc.) or released through agents in combat, such as chemical, biological, or radiation. The latter category is of primary concern. MOPP gear can avert casualty due to the primary agent, but subjects the operator to new stressors, such as heat stress; and

6. combat environment -- defined by the operational mode (e.g., continuous or sustained operations) and mission profile (e.g., deep attack), and the heat of battle.

Each of these environments impacts upon basic abilities and thus changes levels of task performance. More importantly, prolonged exposure to extremes of these environments leads to degradation in capacity to perform and creates a deficit which must eventually be overcome, if ineffectiveness is to be avoided.

The implications for the conceptual framework of environmental stressors are related primarily to characteristics of the theater or area of operations. As such, the characteristics of the environment are predictable and, relatively speaking, constant. Moreover, environmental stressors are the subject of a large body of research and field trials.

<u>Stress-Recovery Processes</u>. In a research note produced in the early stages of this study, DePuy[16] pointed out (in the context of fatigue) that careful attention needs to be paid to opportunities for recovery from the effects of prolonged or frequent stress. In particular, he made reference to the process of "cat napping" and to stress recovery management as embodied in the use of a reserve, the choice of mission assignments or subordinate units, and the intent of cross training in a staff element. Witus,[17] in his examination of historical evidence of human variables in combat, chose a situation (the opening stages of the Golan Heights campaign of 1973) in which opportunities for recovery were essentially not available to the Israelis, and thus observed results of prolonged unrelieved combat stress.

The components of stress present in combat include physical, mental, and emotional stressors associated with the requirements to perform tasks on the battlefield. Depending upon combat situation and vertical

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[16]DePuy, W. (1987).

[17]Witus, G. (1987).

functional system the sequencing of tasks and opportunities for full or partial recovery will differ. Sleep loss is clearly associated with the pattern of demands for task performance as are physical and mental fatigue. The recovery process includes sleep and such factors as food, water, hygiene, socialization, etc.

In the context of the conceptual framework, the stress-recovery process raises a question related to the size of a unit and unit effectiveness. At the level of a small unit or small group, it is reasonable to assume that position in a stress-recovery process is essentially the same for all soldiers in the unit or group, and that the impact on human performance can be assessed in an aggregate way. As numbers of small units are considered simultaneously, for example, in a battalion or a brigade, this is most likely not always the case. Hence the conceptual framework must reflect the distribution of "positions in the stress-recovery process" over the small units or groups that make up a higher echelon unit or formation if estimates of effectiveness are to be made for the larger units or formations.

Impact of Combat. Combat is itself a stressor. It produces uncertainty, generates fear, and, through its dynamics, success and failure of missions, as well as casualties and damage to soldiers and equipment. Uncertainty, fear, and combat outcomes contribute to variations in soldier and small unit performance. Moreover, the impact of these factors is not independent of other processes of stress and recovery. In the extreme fear and uncertainty can immobilize individual soldiers and, at times, the units to which they belong, but such behavior is influenced by most of the factors discussed previously in this chapter.

Intangible Factors. In almost all of the literature of combat and in related behavioral research, attention is focused on factors which are at best indirectly measurable but deemed to be highly significant. These factors include motivation, morale, cohesion, and leadership and initiative. The dictionary definitions of these terms are as follows:

- motivation: an inner drive or impulse, etc. that causes one to act; incentive;
- morale: moral or mental condition with respect to courage, discipline, confidence, etc.;
- leadership (lead): to direct by influence, to show the way by going before;
- initiative: the action of taking the first step or move, ability in originating new ideas or methods; and
- cohesion: tendency to stick together.

These factors pertain to small units or groups when applied to individual soldiers in the case of motivation, morale, leadership and initiative, and to the unit or group in the case of cohesion. They are not easy to measure; they are clearly related and are not independent, and they vary depending upon the dynamics of the combat process. Kellett[18] discusses these factors in terms of their impact on five behaviors:

1. advancing;
2. holding;
3. regrouping;
4. breaking; and
5. non-participating.

DePuy[19] refers to the role of leadership and supervision in overcoming the impact of fatigue within small units. Marshall[20] discusses most of these factors in the context of World War II infantry combat. Within the context of the conceptual framework, these factors are significant and are included as modifiers in all tasks and behaviors.

<u>Framework</u>. Given the factors discussed above, a framework was developed for inquiry into the nature and impact of human variables in combat. The key elements of the framework are as follows:

1. The framework addresses human variables in the context of small units or groups of two categories:

   Category 1: Executing Elements, which are the small units (platoon, squad, maintenance team, etc.) that deliver the combat power associated with a vertical functional system. These units have a leader that performs tasks common to those of other soldiers in the unit.

   Category 2: Command and Control Elements, which are small units or groups whose principal tasks are associated with command and control including planning and mission execution. The commander is considered to be a special member of command and control elements.

2. For the tasks performed by any small unit or group in either of the categories defined above, individual and collective performance is measured in terms of two attributes. The first is selection of a task to perform or behavior to adopt, including a "choice" to do nothing. The second is performance of a task initiated in terms of time, accuracy, and completeness.

3. Baseline task performance is determined by the basic abilities of the soldiers in the small unit, the systems they operate or support, individual and collective training and experience, cohesion, and leadership and supervision.

4. Levels of task performance change as a function of exposure to stress and opportunities for recovery. Stressors include

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[18]Kellett, A. (1980).

[19]DePuy, W. (1987).

[20]Marshall, S.L.A. (1978).

intensity of performance, the ambient environment, and the combat environment.

5. The rate at which task performance changes is a function of so-called intangible factors: motivation, morale, and leadership. These factors are not independent but vary, primarily as a function of combat dynamics and outcomes.

Testable Models and Hypotheses

The perspective of the combat process underlying the conceptual framework, namely, the focus on the activities of the executing elements and vertical and horizontal command and control, led to the formulation of a series of hypotheses, designed in part to prioritize research addressing human variables in combat.

Hypotheses. The first can be expressed as follows:

Hypothesis 1: A small unit's performance in delivering its increment of combat power is dominated by initial conditions which determine opportunities to participate or perform.

This hypothesis derives from the concept of synchronization, namely, the value of being in the right place at the right time. In the extreme, small units fail to contribute to combat power because of failures to be in the right place at the right time --failures caused by deficiencies in command and control or in unit performance. In less extreme cases the conditions which create opportunities, e.g., deployment, preparation, and "battle management" can be such that only a fraction of the unit's subelements can or do participate.

The second hypothesis derives from observations by DePuy,[21] Marshall,[22] and others:

Hypothesis 2: Determination of initial conditions is dominated by leadership and supervision within the small unit and by command and control in the vertical functional system.

This hypothesis reflects the fact that it is necessary to deploy, prepare, and coordinate the elements of a small unit to take full advantage of terrain, to ensure that proper tools and equipment are available, and to ensure that the elements (weapons, specialists, etc.) function as a team. Failures on the part of a superior command and control element cannot easily be overcome. Given appropriate orders and information it is the responsibility of the small unit leader to fight/perform/execute.

The third hypothesis is based on the result reported by Marshall, namely, that only a fraction of the riflemen in a unit participated in firefights:

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[21]DePuy, W. (1987).

[22]Marshall, S.L.A. (1978).

Hypothesis 3: Given opportunities to participate, the level of participation by individual subsystems does not vary significantly.

The final hypothesis addresses performance at the level of individual soldier or system:

Hypothesis 4: Given a decision to participate, soldier or system contribution does not vary significantly.

These hypotheses pertain to the value to overall combat effectiveness of the performance of a task or set of tasks by a small unit or team. Should the hypotheses be verified by research results, a basis would exist for choosing which tasks and which soldiers to address in research on human variables. The third and fourth hypotheses provide general guidance to the formulation of testable models representing human variables in combat.

Testable Models. The framework proposed in this chapter leads to a conceptually straightforward scheme of research -- it defines the scope of any specific investigation, it proposes measures, and it categorizes moderating variables. It also suggests a set of conceptually simple models that are worthy of investigation. These are presented below as components of an underlying model of human variables in the combat process. Generally speaking, they deal with modeling change; that is, baseline performance is taken as given. The central concept is the variation of levels of performance over time in a combat environment.

Task Performance Variation. The first model addresses the pattern of changes in task performance over time. It postulates that for a specific small unit or team task performance level l_p does not change until a time t_1 has elapsed. A rapid degradation (perhaps immediate) then occurs until at time t_2 the task will not be performed if initiated.

Baseline Task Performance Level. The second model addresses the initial level of task performance, l_p. It postulates that the initial level of task performance is a function of basic abilities, training and experience, cohesion and small unit leadership and management, measurable prior to initial task execution.

Environmental Moderators. The third model addresses the impact of environment on task performance. Specifically, it postulates that environmental conditions, properly related to baseline performance measurement, produce a change in task performance related primarily to soldier-system interface.

Stress-Recovery Processes. The fourth model has two components. The first deals with the nature of the stress-recovery process. It postulates that the stress-recovery process can be represented as an alternating series of periods of stress and periods of recovery, with periods of stress and recovery characterized by a measure of intensity or load. It further postulates that for a given set of stressors there are three categories of alternating process characterized by no relief, intermittent relief, and adequate relief. Only the latter does not create a deficit which eventually must be removed. The removal of the deficit has a predictable duration for both of the deficit creating categories.

The second component of this model deals with the relationship between task performance level and the stress-recovery process. It postulates that the relationship is through the time constant t_1 at which performance degrades, i.e., knowledge of the stress-recovery process category sets the time constant.

Intangible Factors. The final model deals with the impact of motivation, morale, cohesion, and leadership. It postulates that the effect of these factors for any given small unit and task is to modify the time constant associated with any given category of a stress-recovery process.

To incorporate dynamic variation in human performance into the framework, a conceptual model of stress and recovery is proposed. It postulates, for an individual, reserves or reservoirs of capacity: physical, mental, and emotional. As illustrated in figure 2, stress is imposed and tasks or activities are undertaken, reserves are depleted, and a deficit begins to build. When opportunities for recovery occur, reserves are restored. It is postulated that there are relationships between the intensity and duration of stress intervals and corresponding intervals in which recovery is possible. In particular, prolonged stress without sufficient opportunities for full restoration of reserves eventually may create a situation in which reserves are fully depleted; in which case, full restoration is required before effective performance at any level can be undertaken. The angles in the exhibit are intended to reflect these phenomena. Angles ϕ_1, ϕ_2, and ϕ_3 are decreasing to indicate that without full restoration, reserves re depleted at a greater rate. Similarly, angle Θ_1 is greater than Θ_2 to reflect a faster rate of recovery. Finally, τ_R represents the time (and resources) required to restore the reserves once the capacity to perform is completely exhausted.

The second component of the conceptual stress-recovery model is illustrated in figure 3. Key to this component is the hypothesis that levels of performance (measured by time, accuracy, and completeness) and behavior (measured by probability of action/non-action and duration) do not change gradually but instead shift between discrete levels as a function ofthe magnitude of the deficit in capacity described above. Baseline performance is a function of the operational environment and soldier attributes. Given a particular stress-recovery process, the time thresholds at which performance changes are related also to soldier.

Summary

The conceptual framework developed in this study has two principal components. The first is a structure, based on the organization of a combat force into executing and command and control elements, that organizes tasks and activities according to battlefield operating systems or vertical battlefield subsystems. Tasks are associated with small groups--teams, crews, or staff elements--and are classified as primary or secondary depending upon whether or not they related to the principal technical function of the battlefield operating system to which the executing element belongs. The second principal component of the framework addresses task performance and behavior. It identifies basic human attributes and assumes that baseline performance is a function of basic abilities and training and

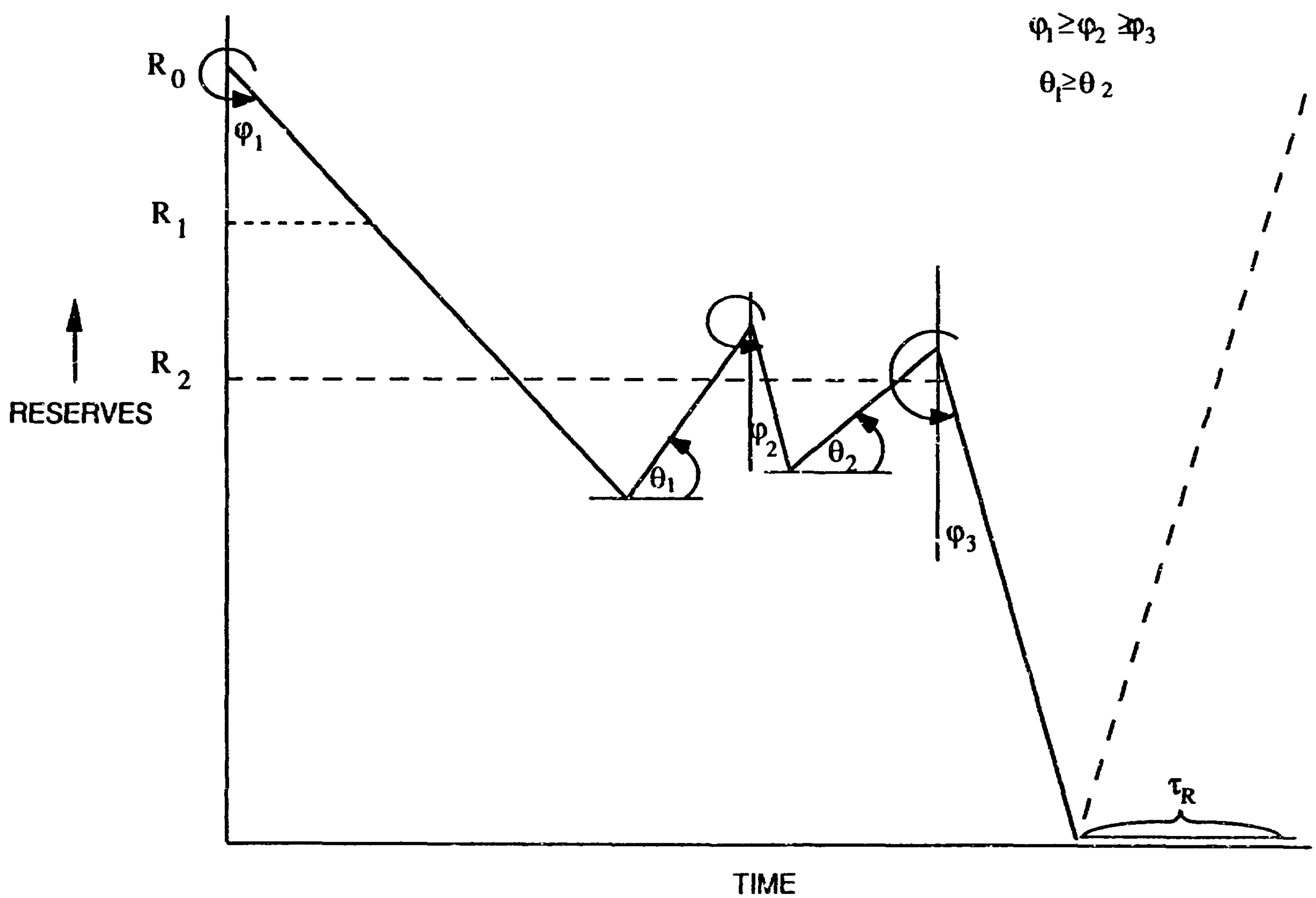

FIGURE 2. STRESS/RECOVERY PROCESS

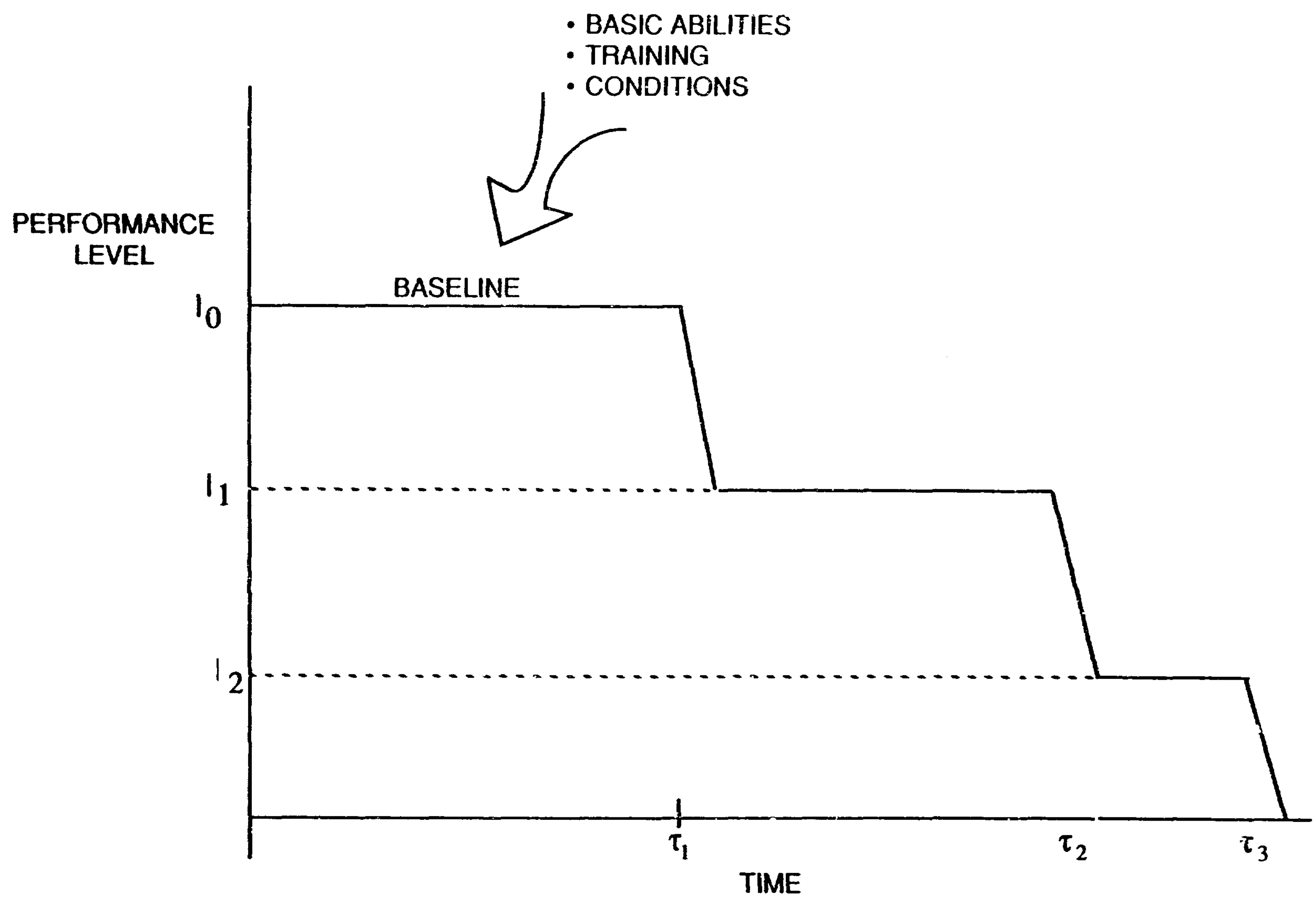

FIGURE 3. DETERIORATION OF PERFORMANCE

experience. It then assumes that the baseline performance is modified by operating conditions, and that it changes in a discrete fashion as a function of stress and recovery patterns. Finally, it is assumed that the major impact of so-called intangible factors -- morale, motivation, leadership, cohesion, and initiative is to change the time constants associated with stress and recovery patterns, in particular, the thresholds at which levels of performance can change.

From the perspective of combat modeling, application of the framework to any given set of tasks performed by an executing element or a command and control element requires that a family of stress-recovery patterns be developed for the task categories. Clearly, baseline operator abilities, training and experience, as well as intensity of task performance are components of such patterns, as is combat results. The impact of operational environment is assumed to be first on baseline performance levels and then, for any stress-recovery pattern, on the rates at which capacity to perform is depleted or restored, represented as ϕ and Θ in figure 2. The assumption of discrete levels of performance relative to capacity reserves requires that the finite number of levels be determined and that thresholds be established at which changes take place (represented as R_i and l_i in figures 2 and 3, respectively), or, equivalently, the time constants of the performance step functions be determined. The final required data relate different sets of values of human attributes to baseline performance and the above mentioned thresholds or time constants (R_0 and l_0 in figures 2 and 3).

CONCLUSIONS

In undertaking this research, three objectives were set:

- to identify human variables that are expected to influence predictions of combat effectiveness;
- to develop procedures for measuring these variables and collecting data; and
- to estimate the nature and level of their effects.

The conceptual framework, developed to organize and structure human variables as they influence combat, focuses attention on the tasks and activities performed by small units or groups and on tasks associated with leadership and command and control. It is the latter tasks and activities, all other things being equal, that are most important since, for example, expert tank gunnery is of no use if no targets are present in an engagement area. This suggests that human performance in leadership and command and control should receive highest priority for research addressing the impact of human variables.

This suggestion is supported by the results available in S.L.A. Marshall.[23] Although those results have recently been called into question, our data appears to support them in kind, if not in quantity. Furthermore, earlier work using high resolution combat models and small differences in terrain and scenario[24] revealed that "only a small fraction (say 20 percent) of the total variance was caused by sampling the attrition processes", that is, in our terms the contribution of executing elements given that they participate.

Baselines for such performance at levels from platoon to corps is not readily available. Until such baselines are established, it is of marginal value to investigate the changes in performance that take place as a consequence of stress and recovery. The key variables appear to be training and knowledge; their impact must be evaluated.

The National Training Center provides valuable data relative to leadership and command and control; from that data it may be possible to develop baselines for brigade, battalion, company, and platoon command and control performance. Such baselines would contribute to improvements in combat models and would provide a starting point for investigating the major role of human variables in determining combat effectiveness. The contributions of executing elements and their performance levels cannot be ignored. However, the results of this research suggest that given present knowledge, the study of human variables in executing elements should be given lower priority relative to execution of command and control activities.

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[23]Marshall, S.L.A. (1978).

[24]Payne, W.B. (1989, January). Personal communication to the author.

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APPENDIX A

ANALYSIS OF SELECTED NTC RESULTS

This analysis of results from force-on-force exercises at the National Training Center (NTC) was undertaken in an effort to disclose the possible relationships that might exist between leadership effectiveness and sleep/rest patterns. Selected mission segments from NTC were examined within the context of the four hypotheses, set forth earlier in the research, regarding the nature of such relationships. In May 1938, we proposed to the Army Research Institute that this analysis be undertaken by extending the NTC Trendline Analyses being undertaken by elements within USATRADOC to a greater level of detail through the investigation of the selected mission segments at the level of independent minibattles within a mission segment. The underlying idea was that such an investigation would fit particularly well within the first two of four hypotheses, restated below, in that each minibattle would represent a particular set of initial conditions, which had been established by the command and staff planning and the leadership effectiveness which ensued from that planning during execution. We here recall the four hypotheses:

- engagement results depend primarily on initial conditions;
- initial conditions depend upon leadership and supervision;
- given initial conditions, levels of participation at the small unit/executing element remain relatively constant; and
- given participation performance does not vary significantly until it falls off dramatically.

The first two hypotheses encompass battalion commanders, battalion staffs, company commanders, and platoon leaders. The planning and supervising activities of this group define and bound the activities of the executing elements. Therefrom, the latter two hypotheses can be addressed in the context of the ensuing minibattles. As will be disclosed and supported in the remainder of this chapter, we found that the first two hypotheses strongly dominate the results of force-on-force engagements undertaken at the NTC. It will be seen from both the quantitative analyses of mission segment data and the qualitative analyses of the After Action Reviews (AARs) and Take Home Packages (THPs), that commander, staff officer, and leader performance are key to the course of events which unfold within an NTC mission segment.

Method of Approach

Both quantitative and qualitative analyses were undertaken. The qualitative analyses consisted of a detailed review of related THPs and AARs with respect, in large measure, to the first two of the four hypotheses. In both planning and execution the performance of key leaders and staff officers was examined in regard to the effects their performance had on establishing the initial conditions and the ensuing engagement results. A taxonomy for this part of the analysis was established as follows:

- Battalion Commander and Battalion S-3;
- Fire Support Officer and Mortar Platoon Leader;
- Battalion S-3 Air and Air Liaison Officer;
- Battalion S-2;
- Scout and Surveillance Platoon Leaders;
- Air Defense Platoon Leader;
- Engineer Company Commander;
- Battalion XO, Battalion S-4, Battalion S-1, and Support Platoon Leader; and
- Company Team Commanders and their Platoon Leaders.

Within this taxonomy and with respect to both individual and coordinated activities we examined planning and leadership performance to determine the effects upon the levels of combat element participation and the degree of battlefield operating system (BOS) synchronization that were realized during the course of a mission segment. In the quantitative analyses both entire segments and the engagements comprising these segments were examined. The focus of the analysis was on minibattles or engagements between opposing groups of the BLUFOR and OPFOR which were established as relatively independent, in time and space, from the remaining engagements, even though some of the minibattles so defined, within a segment, transitioned from one to the other. Thus, a minibattle was a sequence of element engagements within one clearly defined locale where the beginning and ending participating elements changed only as a result of casualties sustained, i.e., no other elements joined in the minibattle during its life span. The circumstance of new elements joining without a cessation in combat constituted another minibattle which transitioned from the previous.

Clearly, the valid partitioning of a segment into the independent minibattles as here defined was essential to the success of this analytic procedure. We began by considering all the force-on-force mission segments. From among these we selected four for further consideration; the remaining six were set aside due to the presence of data voids to such a degree that the needed partitioning could not be accomplished. These four were then examined in greater detail through a review of firing and player location data within a set of minibattles which had been tentatively defined on the basis of paired firing event data. Although the ratio of paired firing events to all firing events at the NTC is surprisingly low, it was hoped that sufficient correlation between the paired firing events and the total population of firing events and player locations would exist that the tentative minibattles could be validated as independent and comprehensive of the whole mission segment. Such was not the case. We then undertook a review of the AAR video tapes in order to gain an understanding of the course of events, within each of the four mission segments, that would be sufficient for establishing and validating a set of minibattles within each mission segment. From this process we were able to establish only one mission segment as possessing a digital data base sufficiently robust that the intended analytic procedures could be applied. Even that mission segment offered only 13 percent of the firing events as paired events; however, through an iterative process of AAR review and detective work with the digital data base we were able to establish what occurred to such an extent that we could proceed with most of the planned analytic procedures.

Measures of Effectiveness

Measures of effectiveness (MOE) in support of the foregoing approach fall into several categories. These involve MOE to measure inter- battlefield operating system (BOS) synchronization, intra-direct fire synchronization, and command and control. The intra-BOS MOE and their intended uses were:

- Within each segment, pairing and firing event, IFCAS missions and minefield encounter counts, and where applicable, element participation rates by type system within each BOS were to be calculated and analyzed. These gross measures were to provide an aggregate understanding of the overall participation levels and synchronization potential for each BOS.

- Within each Δt[1] pairing and firing event, IFCAS mission and minefield encounter counts, and where applicable, element participation rates by type system within each BOS were to be calculated and analyzed:

  - overall and within each Δt; and

  - for each of the several OPFOR target groups (by locale) within each Δt.

The Δts and target groups were here determined on the basis of the minibattle partitioning undertaken earlier; the first of these MOE was to provide a more refined understanding of overall participation levels and synchronization potential, while the second MOE was to provide an understanding of those measures which are correlated in both time and space.

- Within each Δt, engagement range distributions (taken from the existing forward trace of BLUFOR) were to be calculated and analyzed for each BOS. These aggregate measures were to provide information on the employment of each BOS over time within a mission segment and allow comparison with doctrinal norms and environmental limits.

- Within each Δt, pairing and firing event counts and participation rates by type systems, target group (locale), and target type were to be calculated and analyzed. These measures were to allow a detailed understanding to be developed with respect to the levels of participation and degrees of synchronization realized within the

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[1]Meaning the time limits for a minibattle.

mission segment. When considered within the context of the MOE above, tentative inferences could be drawn with respect to the effectiveness of C^2, at both battalion task force and company team levels, as to element participation levels and the degree of synchronization realized.

- Within each Δt, engagement range distributions for each firer-target combination by type were to be calculated and analyzed:
  - overall within each Δt; and
  - for each of the several OPFOR target groups (by locale) within each Δt.

MOE related to engagement aspect angles and overall C^2 were also defined in the original analysis plan. During the course of the analysis these MOE were not calculated and analyzed. With respect to the engagement aspect angles, the NTC data base simply does not provide data refined to a level that would support the intended analysis. With respect to the overall C^2 MOE the digital data base was found to be insufficiently robust to allow the intended chaining of OPFOR target groups through the network of minibattles; we were, however, able to examine overall C^2 effectiveness in a qualitative way on the basis of what was present in the THPs and AARs.

Quantitative Analysis Results

This section is organized into three subsections. In the first, we will present and discuss aggregate results at the mission segment level. In the second subsection the time and space parameters defining five minibattles are presented followed by analysis results at the minibattle level.[2] A substantial use of INGRES was made during this analysis. Where we think it would be helpful to others wishing to undertake a similar analysis of NTC force-on-force trials we have reported the IQUEL queries used in Appendix A. Finally, we will summarize the results of the quantitative analyses, reserving the findings and conclusions following the section on Qualitative Analysis Results. Thus, our findings and conclusions are based upon the results of all analyses undertaken.

Mission Segment Results. Sixty-five paired firing events took place in the mission segment analyzed. Among these, ten were attempted fratricides, all by the OPFOR which resulted in three kills. Fratricide is a real phenomena at the NTC as well as during actual combat. Therefore, anyone undertaking an analysis of NTC results needs to be mindful of this fact in formulating IQUEL queries in a way that readily discloses a fratricide. So, in this case there were fifty-five pairings which involved opposing forces. Surprisingly, these contained only fifteen firings by the OPFOR (attempted fratricides excluded) and forty firings by the BLUFOR. From these firings the BLUFOR achieved nineteen kills and OPFOR achieved six kills. The OPFOR achieved pairings from both tank and BMP firers; however, all pairings achieved by the BLUFOR were solely from its tanks. The

[2]Results from all five minibattles are contained in Appendix A.

pairing rate for this mission segment was 13 percent; we included the fratricides in calculating this pairing rate, assuming that the total population of firings also included attempted fratricides. While the observer-controller made mention of BLUFOR fratricides during the AAR, none were found among the paired event data. This paired event data has its obvious limitations. However, we felt it to be the best from among the ten available to us. The defender/attacker kill ratio is certainly within expected bounds and the locations and times of the paired events afforded sufficient information to structure a tentative set of minibattles. The lack of ITV pairings from BLUFOR was readily explained upon an investigation by their positioning.

A total of 109 IFCAS missions were fired, ninety-four of these by the BLUFOR. In its fire planning the BLUFOR provided a total of eighty-nine target groups. The AAR and THP report very favorably upon the BLUFOR fire planning and execution. The digital data base supports such favorable conclusions insofar as the planning was concerned. However, the digital data base is at total odds with such a finding insofar as execution is concerned; it contains only six kills, all by the OPFOR. This was a regrettable finding in part. On the basis of the AAR and THP reports we decided to disregard the lack of artillery kill data. Thus, we can make no quantitative assessment of artillery/maneuver unit synchronization and must depend wholly on the qualitative analysis results.

The digital data base reflected no OPFOR mine encounters. This was not a surprise to us. As reported later in the section Qualitative Analysis Results, the engineer planning and execution was lacking in several important and unfortunate ways.

The number of BLUFOR systems by type that were instrumented in this mission segment is reflected in figure A-1 along with the number of each system which were killed and which actually fired over the course of the entire mission segment. Even at the aggregate level these data should be of concern. Of 26 tanks, only 12 actually fired and yet 15 were killed; and of 12 ITVs only 3 fired and 7 were killed. In the more detailed quantitative and in the qualitative analyses we sought explanations for these low participation rates. It needs to be noted that in the rotation we examined that the BFV and M113 were not instrumented to fire. In figures A-2 and A-3 we see the distributions of tank and ITV firings within the entire mission segment. The tank distribution is the more revealing. Just 5 of the 26 tanks accounted for 74 percent of the engagements; and only 3 tanks accounted for 56 percent of the engagements. Of the three dominant killers, one was the Commander and one was the Executive Officer of A Company; they fought their own tanks very well, but did not succeed in providing the leadership needed for their subordinates to contribute to the company's mission accomplishment. The ITV distributions of fires presents no better picture; just two of twelve ITVs account for 89 percent of the TOW missiles launched and in the aggregate the average number of TOW missiles launched per ITV over the entire mission segment is only 1.58.

Figure A-4 reflects the distribution of tank engagement ranges over the entire mission segment. Although the mean engagement range of 1207 meters is well below the maximum effective range of the M60 tank there is

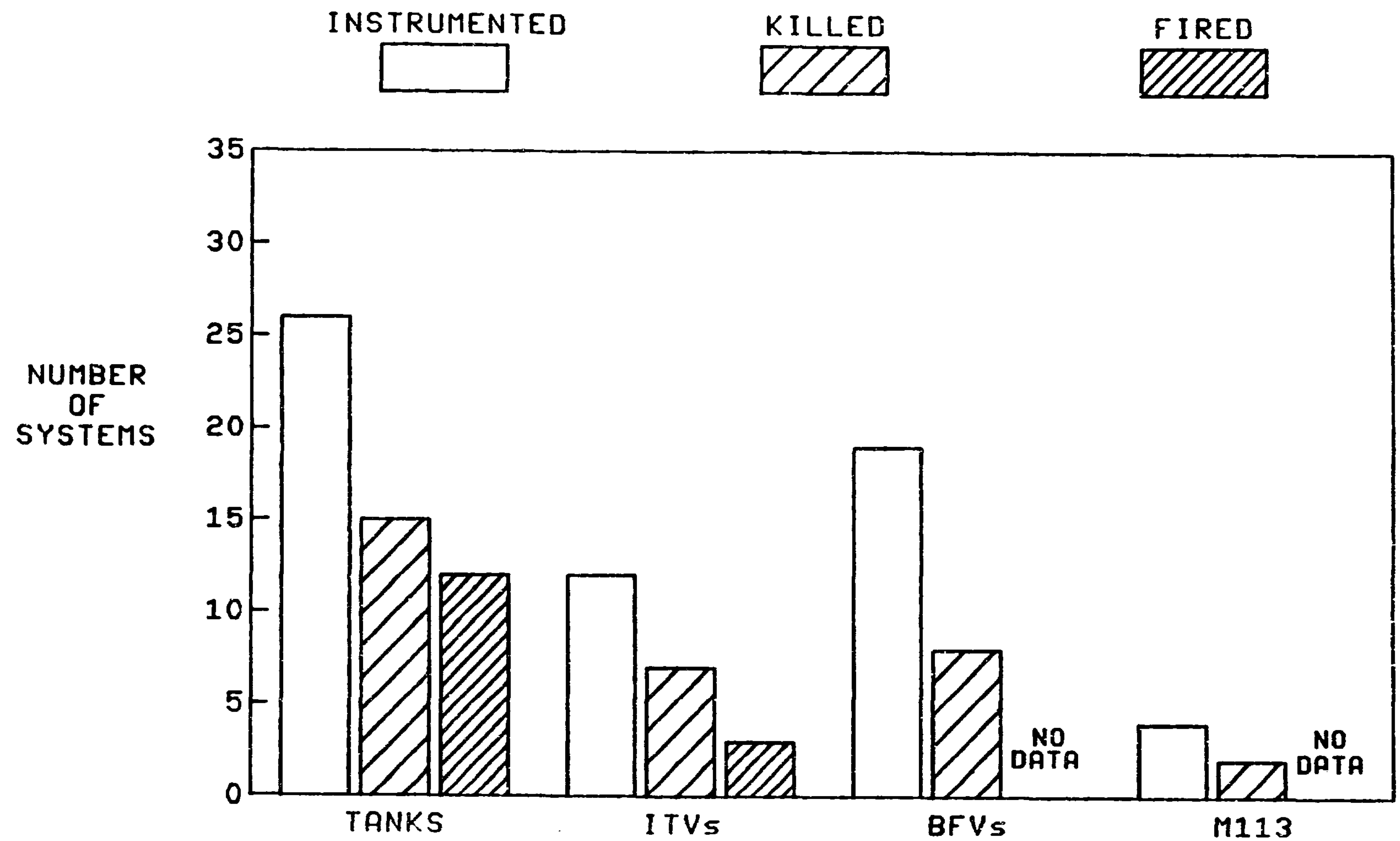
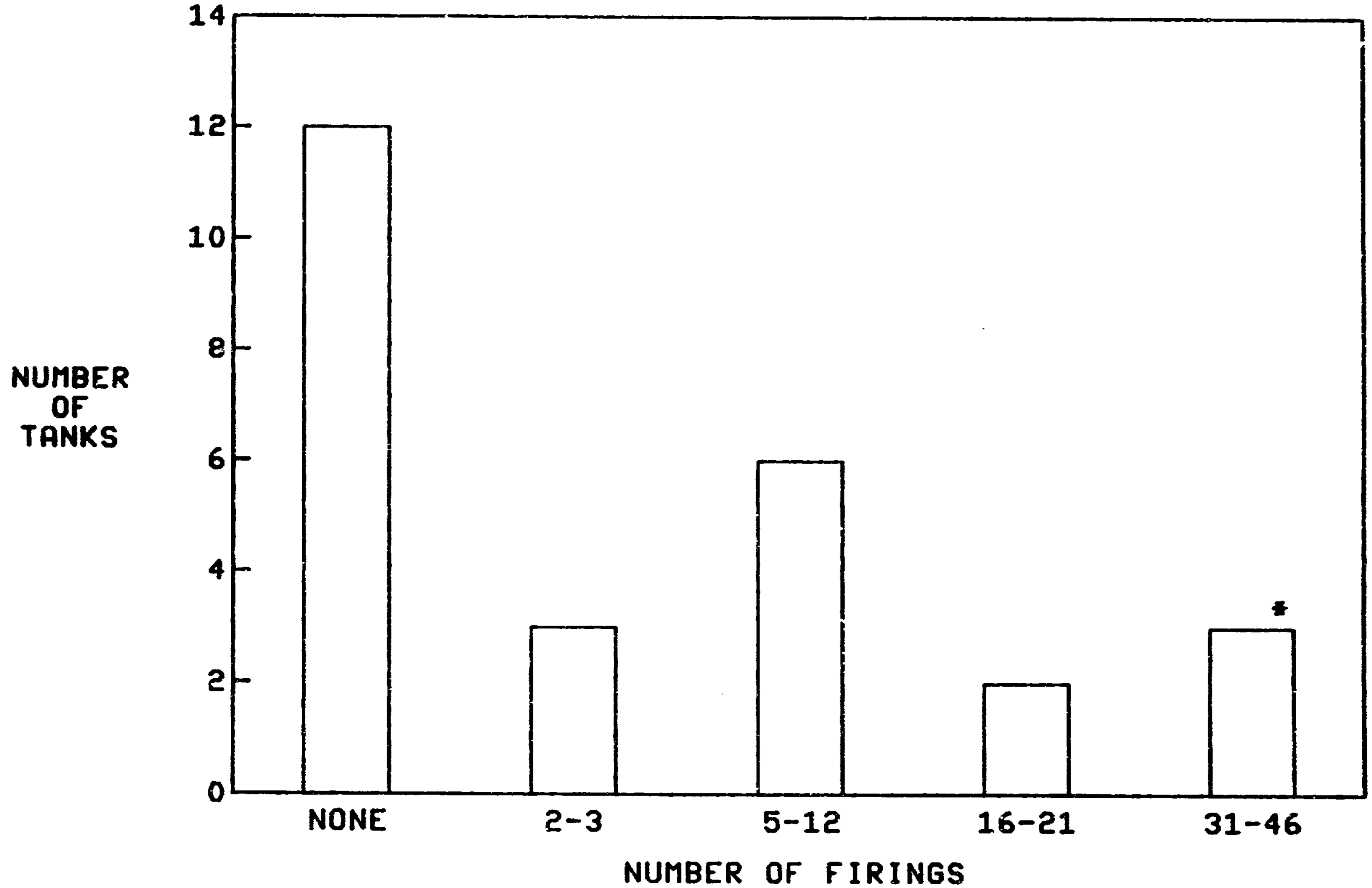


FIGURE A-1. BLUFOR SYSTEMS INSTRUMENTED, KILLED AND FIRING DURING MISSION SEGMENT



* INCLUDES TEAM A CO AND XO

FIGURE A-2. DISTRIBUTION OF TANK FIRINGS

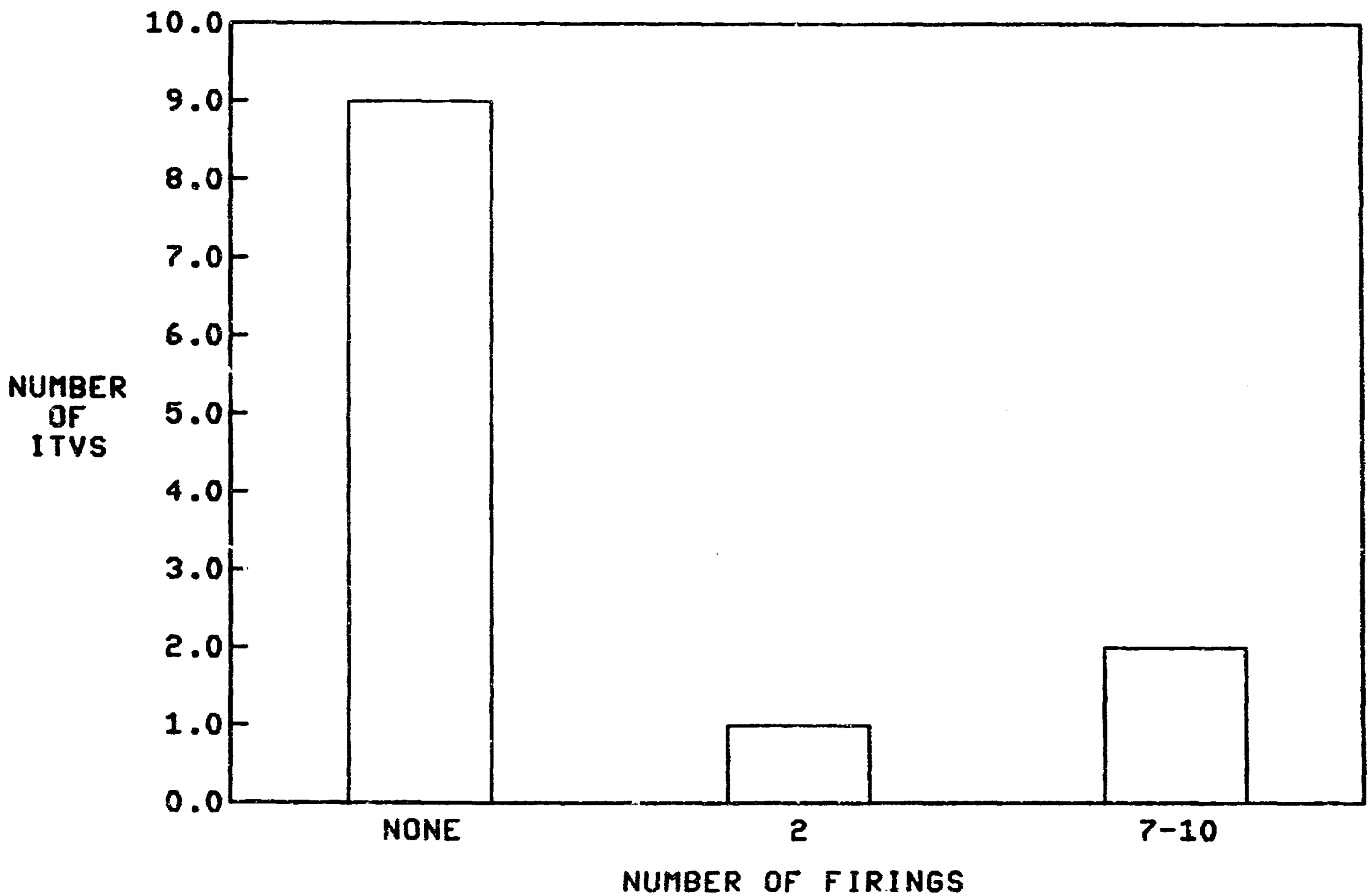


FIGURE A-3. DISTRIBUTION OF ITV FIRINGS

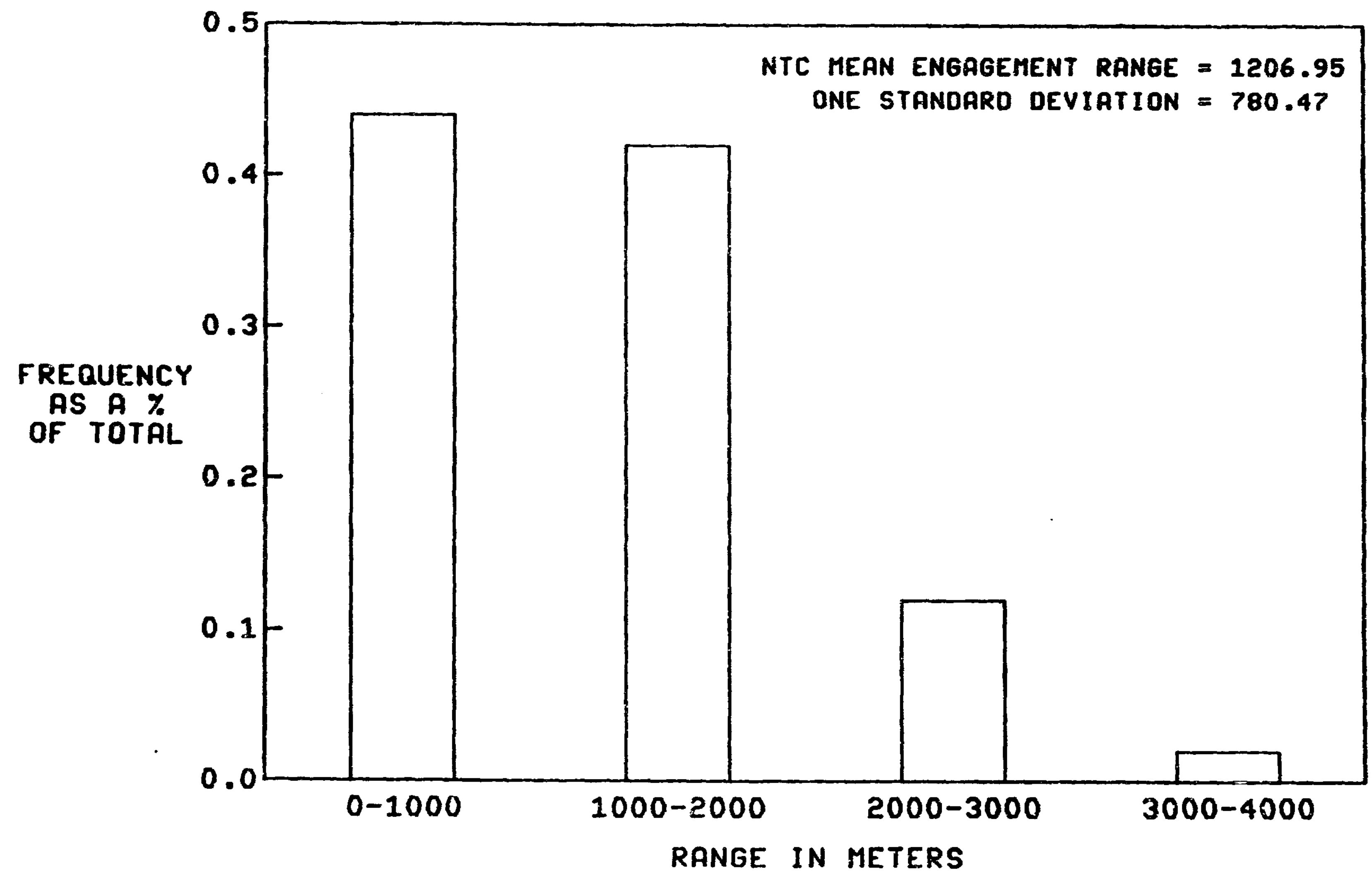


FIGURE A-4. DISTRIBUTION OF TANK ENGAGEMENT RANGES ENTIRE MISSION SEGMENT fairly good balance between the numbers of engagements in the 1000 and 2000 meter range bands. Fourteen percent of the tank engagements do occur at ranges beyond 2000 meters. This aggregated distribution is presented here largely as background information. In the subsection on the minibattle results which follows, we will examine and discuss BLUFOR tank engagement range distributions within the contexts of what the terrain would allow in way of engagement opportunities, the direct fire planning which occurred or not, and the tactical control of fires by small unit leaders.

Minibattle Results. The minibattle structure employed in this part of the analysis is reflected in figure A-5. The locales and time windows of the five minibattles are shown on the sketch. The central fight was in minibattle 1. It involved A Company with three platoons of tanks against two OPFOR battalions. This minibattle transitioned into minibattles 1A and 2 at the times reflected. Minibattle 3A also transitioned from minibattle 1; it involved about one platoon of tanks from A Company and the remnants of the attacking OPFOR battalions. As can be seen, this was a very rapid transition of about five kilometers in just 15-20 minutes. Minibattle 3-B was the first joining of battle between a platoon of tanks from C Company and the few OPFOR elements (four T-72 tanks and one BMP actually fired) which slipped through Red Pass earlier; these OPFOR forces were engaged within the pass by two other tanks from C Company, but only briefly. Of 209 BLUFOR tank firings only 36 occurred sporadically and outside the bounds of the defined minibattles. All of the 36 firings came from five C Company tanks which were deployed widely across the battalion sector, i.e., two were at the northeast mouth of Red Pass and two others in the vicinity of Hill 781E some eight kilometers to the northwest of Red Pass. These wide deployments resulted from repositioning late in the mission segment in response to the battalion commander's perception that the OPFOR's main thrust was coming through Red Pass, which in fact was not the case.

The minibattle analysis and results were presented in terms of paired events, firing events, engagement opportunities, and the range distributions of fires which could be calculated from the recorded paired events.

The table in figure A-6 summarizes the firing event data by minibattle. As mentioned earlier, a total of 209 BLUFOR firing events occurred. The total of 173 discounts the 36 BLUFOR firings which occurred outside the defined minibattles. A considerable disparity in the ratio of paired to all firings exists between the BLUFOR and the OPFOR. Twenty-three percent of BLUFOR's firings were paired, whereas only three percent of the OPFOR firings are paired. The reason for these differences is not known. Possibly, the relative static positioning of the BLUFOR coupled with the larger numbers of OPFOR elements enabled the paired event algorithms to function far better on BLUFOR firings. Clearly, this large difference prohibits the meaningful calculation of any system or force effectiveness calculations between BLUFOR and OPFOR on the sole basis of the paired event data. The firing event data is probably sufficiently accurate that some meaningful and useful insights can be drawn. Overall, BLUFOR did not enjoy the defender's advantage in shots fired. In only two minibattles (1A and 3B) did BLUFOR outshoot the OPFOR. In one of those the BLUFOR had been bypassed and was engaging OPFOR elements into their rear. In the other, BLUFOR had occupied some alternate defensive positions and did realize the defender's advantage against a small OPFOR force to some degree. In

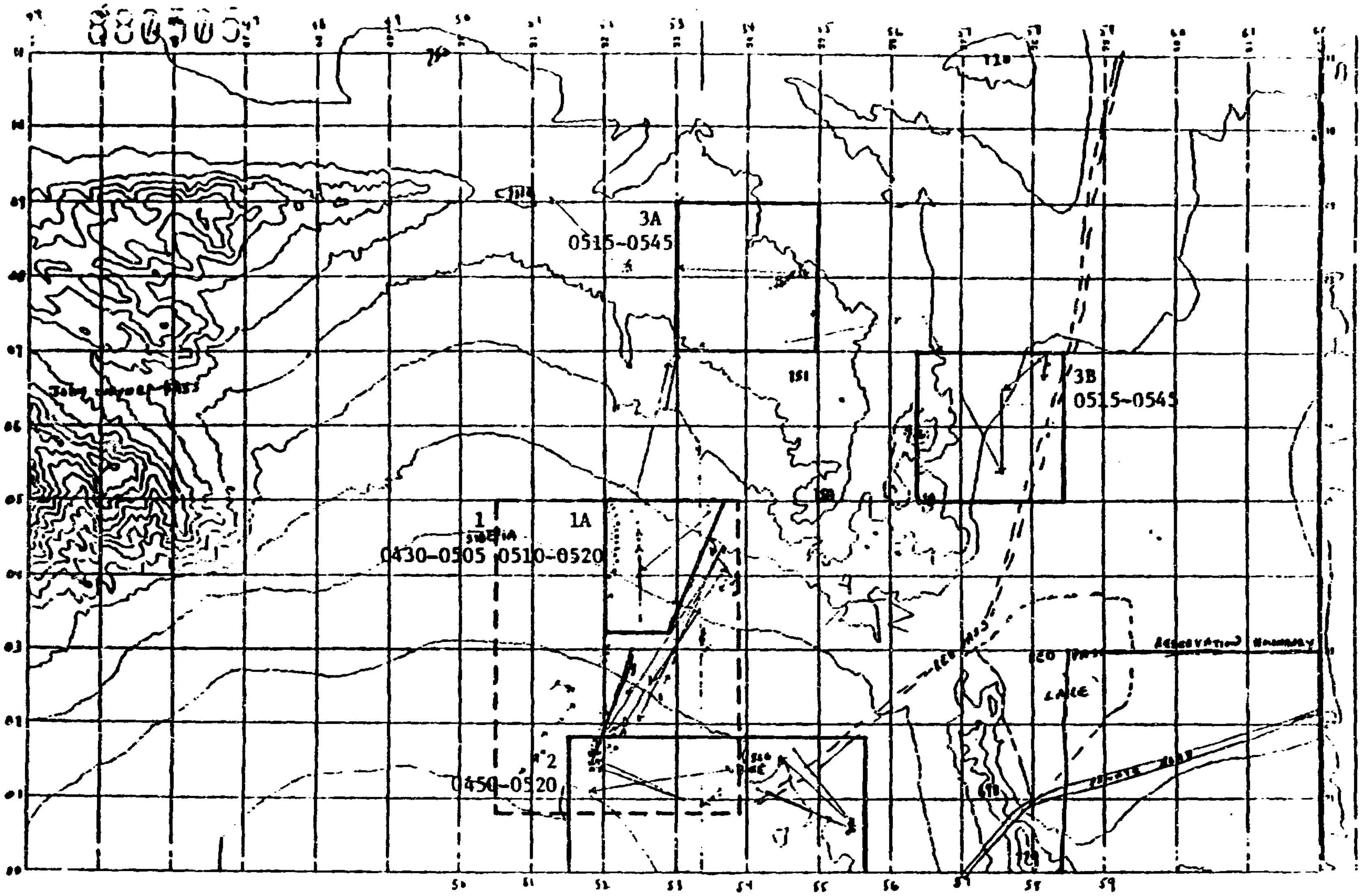


FIGURE A-5. MINIBATTLE LOCALES AND TIMES

	MINIBATTLE					TOTALS
	1	1A	2	3A	3B	
BLUFOR:						
PAIRED FIRINGS	17	3**	8	10	2	40
PAIRED KILLS OF T-72	0	0	2	2	2	5
PAIRED KILLS OF BMP	3	1	1	3	0	8
PAIRED HITS/NO KILL OF T-72	1	1	0	0	0	2
PAIRED HITS/NO KILL OF BMP	4	0	0	1	0	5
ALL FIRINGS	70	10**	39	31	23	173
OPFOR:						
PAIRED FIRINGS	2*	0	5*	2	6*	15*
PAIRED KILLS OF M-60	0	0	0	0	2	2
PAIRED KILLS OF BFV	0	0	2	0	0	2
PAIRED HITS/NO KILL OF M-60	0	0	0	0	0	0
PAIRED HITS/NO KILL OF BFV	0	0	1	0	0	1
ALL FIRINGS	175	0	84	38	19	316

*Excludes attempted fratricides.
**Engagements by Bypassed BLUFOR elements into OPFOR's rear.

FIGURE A-6. TABLE OF FIRING EVENTS BY MINI-BATTLE minibattle 1 where BLUFOR should have had a distinct advantage afforded by excellent defensive positions, the advantage was not exploited effectively for reasons of low participation by the elements in position to fight, as reflected earlier in figures A-2 and A-3, and further exacerbated by the poor positioning of other elements. Of A Company's 14 tanks only six were positioned where they could fire effectively into the company's assigned engagement area CAT, and of these six, 85 percent of the firings came from just two tanks, which were commanded by the Company Commander and the Company Executive Officer. The company's mission would have been better served had they positioned all its tanks in good fighting positions and had ensured through the preparation of a sound direct fire plan and subsequent supervision that all A Company's tanks participated in the minibattle. These points are to be further supported in the section on Qualitative Analysis. Minibattle 2 was the consequence of poor reporting to battalion of the situation as it developed in minibattle 1 and the subsequent decision to have A Company leave its defensive positions and counterattack the nonexistent threat through Red Pass. In this attempted counterattack only three of A Company's tanks, including the Company Commander's and one Vulcan AD gun, succeeded in reaching positions from which they could fight effectively. The OPFOR forces engaged in their flank were, however, attacking north toward hills 758 and 751 and not through Red Pass. These three BLUFOR tanks did achieve a shot ratio of 39/84 or .46 with a locally engaged force ratio of 3/35 or .09. That is a remarkable shot ratio for three M60 tanks against 15 T-72 tanks and 20 BMP. Their individual combat skills, coupled with the OPFOR's decision to continue moving north with all possible speed, enabled this to occur.

To develop a fuller understanding of engagement opportunities versus the engagements which in fact occurred, we requested the assistance of terrain analysis experts from the TRADOC Analysis Command at White Sands Missile Range, New Mexico (TRAC-WSMR). Their help was valuable and enabled us to examine the engagement opportunities for each of the five minibattles. We provided TRAC-WSMR with location and movement data for both BLUFOR and OPFOR elements within each minibattle. Using high resolution terrain models developed at TRAC-WSMR for the analysis of terrain effects on small unit combat, they provided us with resulting line of sight data, inview and out-of-view segment length data, and first and expected opening range data for each of our minibattles. The analysis results for each of the five minibattles are presented in appendix A to this report. A summary of the results for minibattle 1 is included in this subsection. The probability of line-of-sight for minibattle 1 is shown in figure A-7. When coupled with the inview segment length data in figure A-8 it can be readily seen that the assigned A Company defensive position afforded excellent engagement opportunities against a force attacking north toward hills 751 and 758 from positions west of Bone (see figure A-5). These line-of-sight and inview segment length data are <u>empirical</u> data actually calculated on an element by element basis from the position and movement data provided. Excellent line-of-sight conditions prevail well beyond three thousand meters. Ample defensive positions for a full company of tanks existed here. The mean inview segment lengths <u>and</u> the associated distribution reflect that many long segment lengths exist, which would not only afford manifold engagement opportunities for tanks but also for ITV.

It will simply be noted here that <u>no</u> ITV within the battalion task force were positioned with A Company. In fact, all 12 ITV were positioned

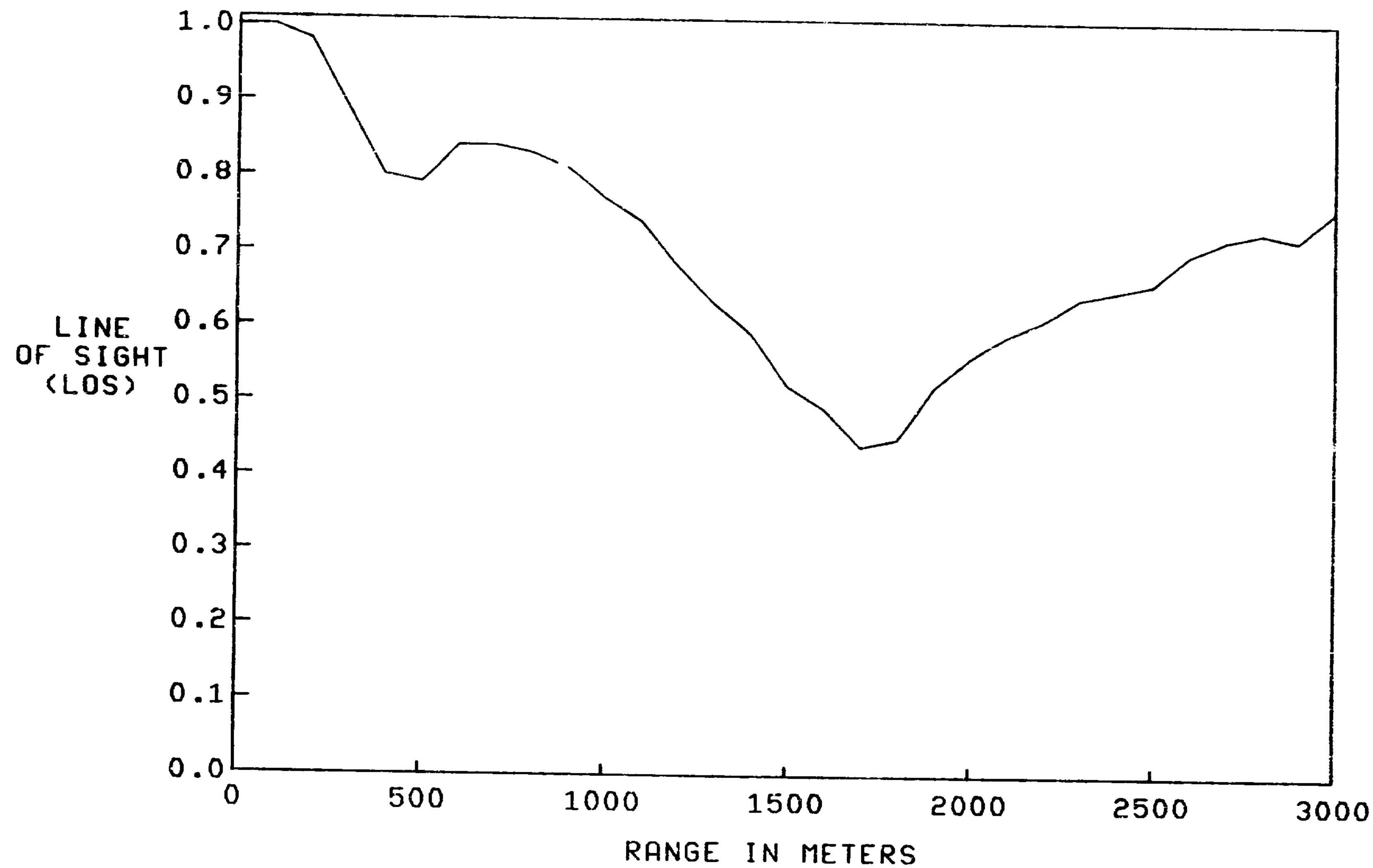


FIGURE A-7. BLUFOR PROBABILITY OF LOS MINI-BATTLE 1

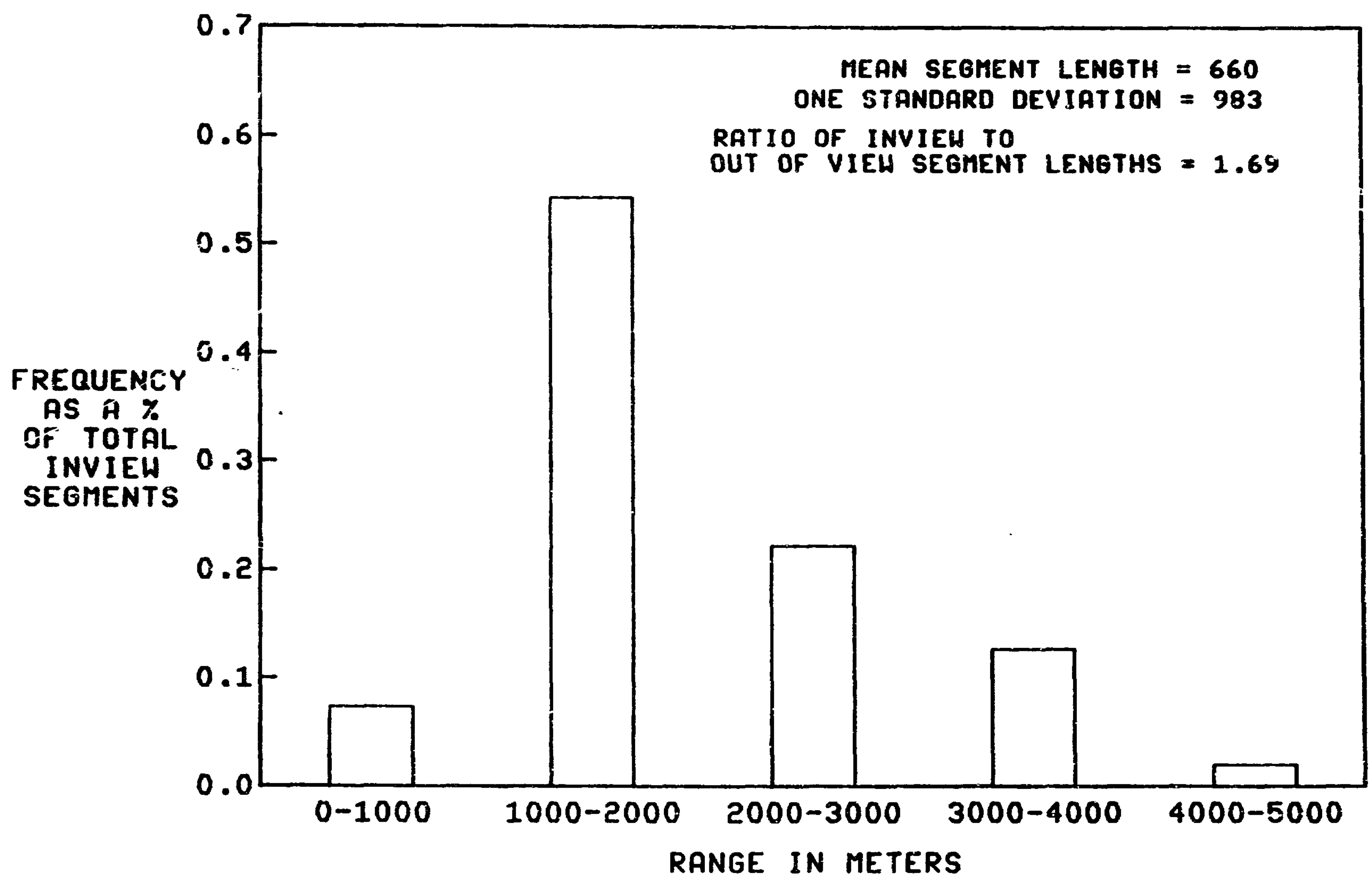


FIGURE A-8. DISTRIBUTION OF INVIEW SEGMENTS MINI-BATTLE 1 to the rear on the forward slopes of hill 720. This point will be amplified on further in the section on Qualitative Analysis. The point here is that ample engagement opportunities would have been presented had some ITV been positioned forward with A Company. The ratio of inview to out-of-view segment lengths reflects that the mean out-of-view segment lengths were in fact of much shorter duration than the inview segment lengths. The desirability of A Company's assigned battle position as a defensive position is further emphasized in figure A-9 where we have presented the distributions of first and expected engagement ranges from the TRAC-WSMR analysis along with the actual distribution of tank engagements from minibattle 1 at the NTC. Although only five BLUFOR tanks actually fired during this minibattle, the performance of these crews reflects a high level of crew proficiency in target acquisition and engagement. In the 1000-2000 and 2000-3000 meter range bands engagement performance met the expected opening range predictions from TRAC-WSMR. As the TRAC-WSMR analysis considers only terrain effects and not acquisition and effective range capabilities the lower NTC performance at the extended range should not be a cause for concern. The higher actual percent of engagements at the 0-1000 range band probably reflects an acceptable shift in the actual versus expected engagement range distributions due to actual acquisition capabilities. The data support the statement that the tank crews which did fire in minibattle 1 performed well. The lack of mission success resulted from small unit leadership shortcomings in the positioning of the tanks and in the preparation of an adequate direct fire plan and follow-on supervision by small unit leaders.

<u>Summary of Quantitative Analysis Results</u>. The foremost area of concern coming from the quantitative analysis has to do with the levels of participation and intra-BOS synchronization. From among the instrumented BLUFOR systems an aggregate participation level of 39 percent was realized; yet 58 percent of the total instrumented systems were killed. Thus, 19 percent of BLUFOR's tanks and ITV served simply as targets for the OPFOR over the course of the entire mission segment. Clearly, the synchronization potential among only the direct fire systems is severely limited by such a low participation level. In a defensive operation, when only 12 of 26 tanks and 3 of 12 ITV actually take part in the battle, the potential value of any synchronization of these direct fire systems with the indirect fires, attack helicopter and close air support, and barriers and minefields, is greatly reduced. There were no OPFOR mine encounters reported in the digital data. Although the indirect fire planning was commendable and somewhat effective according to the AAR and THP derived data, to be covered in the subsequent section, it will be seen there that poor reporting on the ongoing battle situation and insufficient contingency planning and rehearsals substantially negated effective inter-BOS synchronization. The data contained in the digital data base certainly bear this out.

The tanks which participated in the battle were well positioned and their effectiveness in the battle reflects a high level of crew proficiency. Non-participation in the battle by 14 tanks cannot be explained fully from the digital data base. Two of the A Company non-participants were found in the ground player location table at locations 10-12 kilometers from the battle positions assigned to A Company. Three of C Company's tanks were found in positions at the northeast mouth of Red Pass;

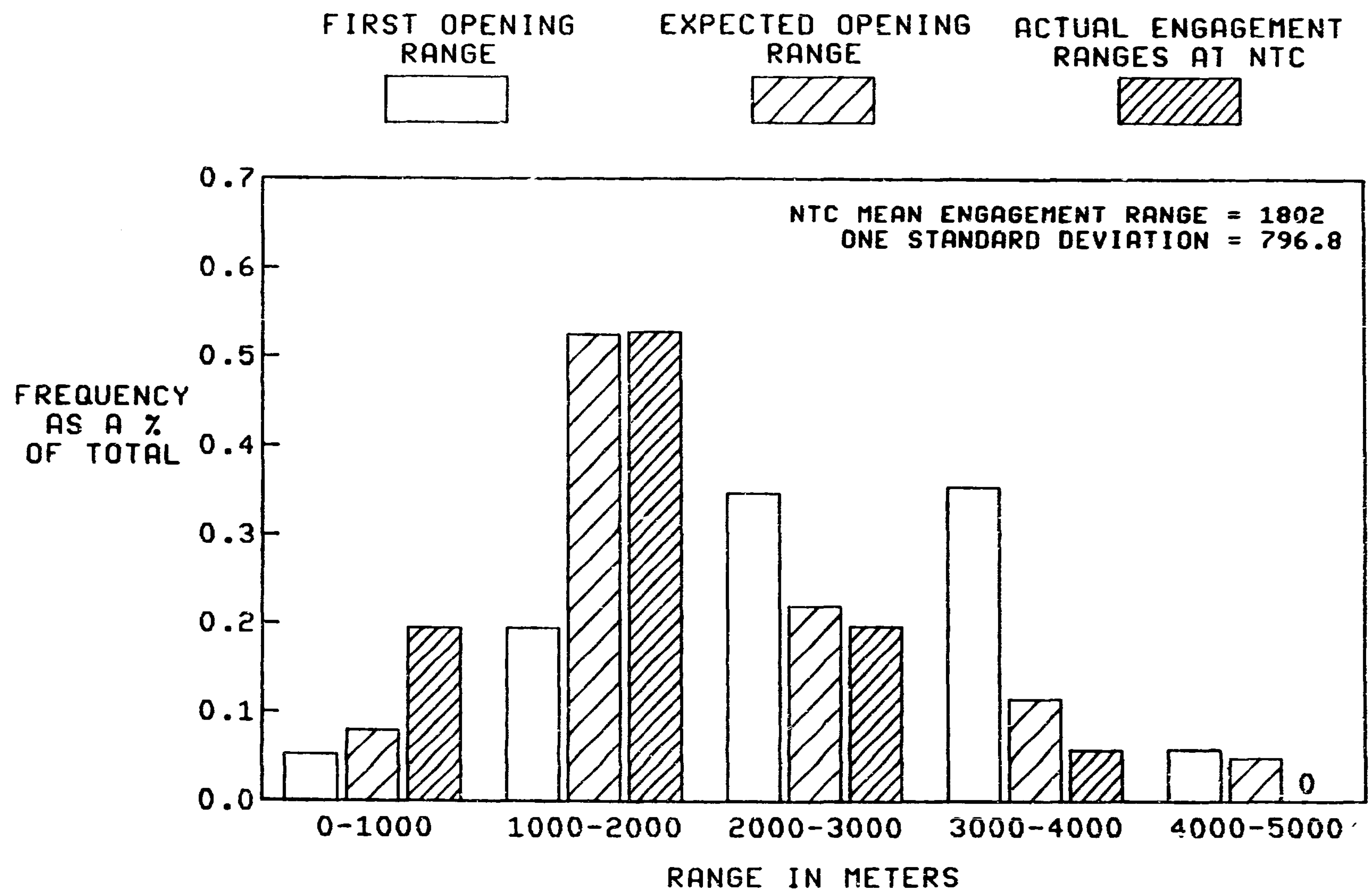


FIGURE A-9. DISTRIBUTION OF FIRST AND EXPECTED OPENING RANGES AND ACTUAL TANK ENGAGEMENT RANGES AT THE NTC MINI-BATTLE 1

2 of 3 three fired 22 rounds at a small OPFOR force negotiating the pass. Five of C Company's tanks move from their initial battle positions to the C Company alternate battle position, but three of them did not participate in minibattle 3B upon their arrival there, as their two companions did. So, from an employment standpoint the actual participation levels may have, in fact, been slightly higher than the digital data base indicates, but not sufficiently high for us to state that the participation level for tanks was at the doctrinal level.

All of the ITV from E Company are deployed initially on the forward (southern) slopes of Hill 720 and remain there with only local repositioning taking place through the course of the mission segment. It is not until the very end of the mission segment, when the outcome of the battle is decided clearly, that any of them can even range the OPFOR. Then, as stated earlier, only 3 of the 12 engage the OPFOR; but by then they can contribute nothing to the battle's outcome.

Overall, there is ample evidence in the quantitative results that effective command and control, i.e., adequate planning and preparation for the defense, and situation reporting and assessment along with timely sound frag orders and responses, simply did not occur during the conduct of this mission segment. The qualitative analysis, which follows, will bear out this finding strongly.

Qualitative Analysis Results. The qualitative analysis was undertaken in two parts. In the first we reviewed the brigade and battalion operations orders and the battalion after action review (AAR) to gain a full understanding of what occurred during the mission segment so that the quantitative analysis would be accomplished within the context of that understanding. During the second part we revisited the AAR, including the one company team AAR which exists, and studied the pertinent sections of the mission segment take home package (THP). Our purpose here was to complement the quantitative analysis, in respect to levels of participation and degrees of synchronization realized, with the judgments rendered by the NTC observer-controllers. The AAR and THP based analyses make an important contribution to this research and to the findings and conclusions we have drawn. Consequently, upon its completion, we elected to review four additional AARs of similar mission segments from other rotations chosen at random to determine if the mission segment analyzed was alike or not in its conduct and results to comparable mission segments from other rotations. A summary of this review is contained in Appendix B. The taxonomy used in accomplishing this analysis was the one stated in the Method of Approach. That taxonomy reflects the structure of the AARs. We have chosen to present the results in terms of the THP structure, which is done with respect to the following operating systems:

- Intelligence;
- Maneuver;
- Fire Support;
- Air Defense;
- Mobility/Countermobility/Survivability;
- Combat Service Support; and
- Command and Control.

Intelligence. A thorough and well done intelligence preparation of the battlefield (IPB) is essential to the conduct of an effective defense. In the terrain analysis it is essential to identify the avenues of approach and mobility corridors available to the OPFOR and then, coupled with a thorough knowledge of OPFOR offensive doctrine, to develop a decision support template (DST), that enables the battalion S-2 to track the OPFOR situation as it develops. This should be accomplished in reference to named areas of interest (NAI), which are related to the avenues of approach and mobility corridors throughout the depth of the expected battlefield. Spot reports with respect to these NAI coupled with predicted OPFOR decision points then enable the Battalion S-2 to track the OPFOR's advance and develop his chosen course of action sufficiently early that the commander and battalion S-3 can synchronize the application of combat power against the OPFOR through the supporting fires from artillery, attack helicopters and CAS, and needed repositioning of maneuver elements. In this mission segment the S-2's IPB was inadequate. It failed to identify all the mobility corridors and avenues of approach, including the one used by the OPFOR's main effort. NAIs were not wholly related to the principal avenues and did not extend through the depth of the battalion task force's sector. The DST was inadequate and in particular did not identify the OPFOR decision points. Reporting of the developing situation was poor, particularly from the Scout Platoon and A Company. The main OPFOR thrust came against A Company. As reported in the section on Quantitative Analysis, those A Company elements in position to do so fought effectively. Yet no reports were made to the battalion task force TOC. This absence of reports from A Company, coupled with erroneous reports (presumably observer-controller input) from higher headquarters, led the Battalion Commander to conclude erroneously that the main OPFOR effort was being made through Red Pass.

A very important consequence of all the foregoing was that although the OPFOR was acquired early, effective tracking was not maintained, the OPFOR's actual course of action was never developed, and little was provided to the Commander, his S-3, and his FSO on the expected sequence of events.

The activities of the Scout Platoon are especially worth noting. The platoon had the mission to screen from the Whale to the base of Tierfort Mountain as the battalion task force prepared to defend to the North. On the night prior to the attack, the OPFOR penetrated with two BRDMs and inserted dismounted OPs deep in the defensive sector; this escaped all notice of the Scout Platoon which was deployed on the north (friendly) side of the Whale. The following afternoon a small force of OPFOR tanks and BMPs attacked and secured the Whale, killing an M1, an M3, and a GSR track; three BMPs and three T-72s were killed in this fight. Shortly after this OPFOR attack was launched, the Scout Platoon leader on his own killed seven BMP and about sixty OPFOR troops as they attempted to dismount a company on the southwest side of the Whale. In spite of this significant and commendable individual action, the platoon leader chose to leave his platoon deployed on the north side of the Whale. Finally, the platoon leader took under fire the main elements of the OPFOR regiment and was quickly killed himself. At no time during these actions were spot reports provided to the battalion task force TOC from the scout platoon. The scout platoon did inflict substantial casualties on the OPFOR, but failed in its two important functions of counter-reconnaisance and development of an accurate picture of the OPFOR situation for the Commander.

Maneuver. The commander's concept for the defense was sound, although a bit complicated in that it provided for five contingencies. However, two important limitations foiled its successful execution. The first of these was the failure to "see the battlefield" and track the OPFOR as presented in the foregoing subsection. The second was that the operations order failed to convey the commander's concept in sufficient detail that it could be understood thoroughly enough for adequate position preparations and direct fire planning to be undertaken for effective coordination to occur among the company team commanders, the FSO, and the engineer, and for adequate rehearsals of repositioning schemes to happen. The commander's intent simply was not adequately understood.

As a consequence, a number of failings in planning and preparation greatly reduced the effectiveness of the defense. Among the most significant were:

- the defense plan was not built around adequate engagement areas;
- obstacles were not planned to support the commander's concept;
- plans to control and mass direct fires were inadequate; i.e., target reference points (TRPs) were not selected and range cards were not prepared;
- repositioning schemes were not rehearsed adequately, and repositioning decision points were not adjusted to the governing time and distance factors; and
- the engineer's effort was not coordinated between the engineers and company team commanders.

The battle which ensued was intense. Although the BLUFOR inflicted about fifty percent attrition on the OPFOR the cohesiveness of the defense was lost. A lack of synchronization between the barriers and direct fires, failure to track the OPFOR situation as it developed, and the loss of both control and purpose during the repositioning of maneuver elements were the major contributors. The obstacle associated with the task force's primary engagement area CAT, in front of A and C Companies was placed about 300 meters too far forward. As a result, the launch of about 100 TOW missiles from the BFV and the firing of many tank rounds rendered only seven TOW kills and two tank kills. The OPFOR was simply stopped short of the intended engagement area over a period of twenty- five minutes. Similarly, the planned FASCAM was fired too early, resulting in only one tank kill. And in front of E Company, where all 12 ITV were employed on the southern slopes of Hill 720, there were no obstacles even planned in order to lengthen the engagement windows of the task force's slowest firing antitank system.

Since the battalion's primary engagement area with respect to the center avenue of approach afforded excellent defensive positions with long range fields of fire and long inview segment lengths, it is difficult to understand why some of the ITV were not initially attached to A Company, where they could have substantially thickened the long range anti-tank fires. The IBP shortcomings and poor spot reporting during conduct of the defense led to an erroneous assessment of the OPFOR situation as it developed and the ill-advised repositioning of major elements from within A, B, and C Companies. Finally, as that repositioning occurred control was lost and the battle became one of isolated engagements, as the surviving OPFOR forces sped their way onto their objective defended solely by E Company's ITV. What if the OPFOR had been adequately tracked, the obstacle associated with CAT properly placed with A and C Companies remaining in their good defensive positions? The commander's concept was sufficient to conduct an effective defense against the OPFOR's chosen course of action had adequate planning and preparations taken place with respect to S-2's decision support template, the obstacle locations, and the forward deployed company team positions and their direct fire planning.

Fire Support. In general, the fire planning and execution was reported on favorably in both the AAR and THP. As mentioned earlier in the section on Mission Segment Results, this statement is at odds with the digital data base. Since the NTC digital data bases include many data voids and some data contradictions we have assumed the observer-controller reports to be the more accurate where there is disagreement. There were three matters which merit mention. First, early in the battle good fire planning and effective coordination between the forward deployed forces and the FSO resulted in devastating effects on the lead MRB from artillery fires. Second, the less than adequate IPB and poor reporting prompted delivery of artillery fires into a group west of D Company's battle position in the vicinity of Red Pass; however, the OPFOR had turned north and the group had no effect when fired. Last, there was a lack of adequate fire planning in the task force's rear around E Company's position where artillery fires were not employed effectively against the OPFOR following his breakthrough.

Air Defense. Air defense planning was not a coordinated effort. Each group of air defense was deployed to protect its own asset without knowledge of where any other air defense systems were deployed. Weak troop leading procedures contributed to poor preparation of air defense positions and little effectiveness during the battle's conduct. Weak relationships between the company teams and the STINGER teams resulted in individual fighting positions not be constructed for the STINGERs. Directly pertinent to the purpose of this research was the air defense platoon leader's failure to ensure effective sleep management with the consequence that STINGER gunners were found asleep during periods of high air threat on several occasions. During the battle the platoon leader did not position himself with the Vulcan platoon, causing significant command and control problems.

Mobility/Countermobility/Survivability. Substantial engineer support was provided the task force in the form of a divisional engineer company with a fourth platoon attached, four bulldozers, and a bucket loader. Due principally to a lack of effective time management by the engineers only 3700 mines of 8000 available were delivered to the task force. This severely limited the task force's countermobility effort. As mentioned earlier FASCAM was erroneously emplaced early without release from division and had little effect. Engineer planning began late with the consequence that only 2400 mines were emplaced, and these emplacements occurred without coordination between the engineers and ground unit commanders. As a consequence, obstacles were generally not covered by direct fire and were easily bypassed by the OPFOR. In the one case where the OPFOR was delayed, as mentioned earlier in the section on Maneuver, the obstacle was poorly placed, substantially reducing its effectiveness. All in all, the countermobility plan and execution failed in the aspects of volume, density, depth, and timeliness.

Combat Service Support. Combat service support performance by the task force was limited by the omission of guidance in the Brigade order. At the company team level there was a dearth of reporting to battalion on the CSS status, an absence of CSS planning, and a failure to conduct resupply and maintenance operations in a tactical manner. At the battalion's task force level the S-4 did not exercise centralized control of CSS operation, nor did he stay abreast of the tactical situation. As a consequence, no recovery operations were performed, the forward aid station was destroyed, and sustainment of classes III and V resupply was lacking. Had the battle been extended, both ammunition and fuel shortages would have been manifested at the company team level.

Command and Control. The brigade command post did not set the mission segment off well for the battalion task force actually being exercised in that an orderly staff planning process was not used. In particular, courses of action were presented concurrently with the mission analysis, and the mission was not war gamed until after the order was published. The battalion task force's plan lacked sufficient detail to facilitate adequate preparations and control of a defense in sector. Decision points were not identified where the OPFOR would necessarily have to commit to a particular avenue of approach and thereby not utilized to resposition BLUFOR forces in order to mass fires on the OPFOR. Thus, timed rehearsals of the several repositioning schemes were not conducted. Engineer obstacle planning and emplacement was particularly poor. Only 30 percent of the available mines were emplaced and these were not coordinated with the company teams as to their siting. No obstacles were planned in front of E Company. The overall results were no mine encounters by the OPFOR, as reflected in the digital data base, and no contribution to the effectiveness of the defense from the obstacles that were emplaced. Inadequate spot reporting, coupled with the inadequate decision support template, resulted in the decision to reposition major maneuver forces on the wrong avenue of approach; according to the THP this decision was based upon just one spot report from D Company, which reported less than a half dozen OPFOR vehicles as a battalion and an otherwise unconfirmed report from division. The three overall findings on command and control in the THP were:

- the (battalion task force) plan lacked sufficient details to facilitate control of preparation (for) and execution of the defense in sector;
- there was poor management/supervision of the preparation efforts; and
- it was a poor decision to reposition early. The task force lacked initiative and agility to get back on the enemy in a timely manner.

Findings and Conclusions

Findings. From a combination of the quantitative and qualitative analyses we have drawn sixteen major findings in regard to this mission segment. These center around the first two of the four hypotheses advanced earlier in this research; yet only one of them deals directly with the issue of sleep/rest patterns and leadership effectiveness. The principal findings of this part of the research are the following:

- the NTC digital data base, while sufficient to support some quantitative analysis, is incomplete and in some instances contradictory within itself or with other data contained in the AAR and THP;

- the BLUFOR counter-reconnaisance was ineffective;

- BLUFOR participation in the battle was low for all major systems by any reasonable doctrinal expectation;

- among the participants, there exist a few "killer" systems who participate substantially more than all others;

- terrain effects will not explain the foregoing finding; in this mission segment the terrain afforded enough defensive fighting positions that all BLUFOR elements could have had ample engagement opportunities;

- all of the ITV were positioned where they could not bring their fires to bear on the OPFOR until late in the mission segment when the battle's outcome had already been decided;

- the BLUFOR elements which did participate fought well; acquisitions occurred at expected ranges and the unit's gunnery was good;

- due to low participation, apparently caused by both poor positioning and inadequate supervision by small unit leaders, BLUFOR did not enjoy the defender's advantage;

- artillery fire planning was generally good, but incomplete, i.e., fires were not planned to the depth of the battalion task force sector;

- there was insufficient detail in the battalion operation order, misunderstanding of the commander's intent, and inadequate preparations for the defense were the consequences;

- similarly, there were insufficient rehearsals and inadequate preparations for the effective execution of plans related to maneuver unit repositionings;

- there was a total lack of coordination between company team commanders and the engineer on the siting of minefields and obstacles;

- the IPB was inadequate to allow commanders and leaders at all levels to track the OPFOR and ascertain the OPFOR course of action as it developed;

- spot reporting of the ongoing situation was wholly inadequate throughout the entire mission segment;

- the foregoing two findings contributed substantially to an early repositioning of maneuver forces against the wrong avenue of approach and away from the avenue which the OPFOR was in fact using; and

- the lack of an adequate sleep management plan adversely affected the performance of STINGER crewmen; this is the sole reference to sleep loss in all the available data, except for a general remark by the chief observer-controller at the battalion task force AAR that he "saw some blurry eyes".

Conclusions. The minibattle approach which we undertook is a viable one for the purpose of analyzing the results of an NTC force-on-force mission segment in detail. Because of the current voids and sometimes questionable data in the NTC digital data bases it must be applied in close conjunction with the AAR and THP. Although viable in the sense of being useful in this analysis, we cannot, on the basis of this research, state that it is always possible to construct a network of independent minibattles from the results of a simulated battle. However, that remains a very interesting question from at least two perspectives. First, such an approach can facilitate the analysis and understanding of what took place in a simulated battle of interest through being able to examine what occurred during each of the independent nodes (presumably unperturbed by exogenous influences) and to understand how the battle's ultimate outcome took place as a consequence of the transitions which occurred among the minibattles. Second, the structure of a network of minibattles might well provide a modeling framework wherein attrition algorithms can be applied independently within each minibattle, allowing the validity of the simulated results to be assessed in regard to the structure of the network as it is brought into being by the influences of the environment, opposing C^2 processes, and external support.

Lastly, we have drawn a set of conclusions in regard to training emphasis. The value of the NTC experience could likely be increased if small unit leaders, by virtue of training at their home station, arrive at the NTC with a greater appreciation and understanding of the benefits to be realized from accomplishing detailed coordination with adjacent, and, in particular, supporting elements, proper supervision of their subordinates in preparation for and conduct of tactical missions, and in reporting of the developing situation to their higher command elements. While the use of ARTBASS and other battalion level C^2 simulations can benefit the battalion level in this way, its benefits probably do not extend to company commanders, platoon leaders, and key non-commissioned leaders to the extent needed. Home station exercises and other training means need to be developed and brought into use which for small unit leaders emphasize the importance of:

- coordination with artillery FSOs and FISTS, engineer, and close air support (AH and CAS);

- supervision of subordinates in the preparation of positions and range cards, target acquisition, target selection, and target engagement; and

- reporting of all significant activities with accuracy and completeness as they occur.

Possibly, protocols and training vignettes for use in SIMNET as it comes into being can satisfy this need. However, we also conclude that other less expensive, more quickly realized training means need to be developed and put to use in Army training at home station to meet these needs.

Similarly, more emphasis needs to be made in training at home station in staff planning and supervision. In particular, the training of battalion S-2s in IPB and the full inclusion of his activities into both planning and tracking of the battle require emphasis. Battalion level CPXs and the use of battalion level C^2 simulations need to emphasize more than just staff procedures. The substance and detail of IPB needs to be brought to the foreground in staff exercises. For example, in the defense, DST and contingency plans need to be developed in detail. Then an external control element needs to provide the situational inputs needed for the battalion commander and his staff to assess a developing dynamic situation and to make the necessary decisions for repositioning forces and employing combat support vis-a-vis the simulated opposing forces in a timely and synchronized manner.

Finally, home station training must be stressful in the sense that all participants develop an appreciation of and the individual techniques needed to enable effective time management. It is universally true in the NTC results we have examined that effective time management is a severe challenge to all who enter the NTC training environment. The value of task delegation must be learned and practiced to the degree possible prior to the NTC experience. Unit standard operating procedures need to spell out these task delegations in detail. Subordinates must know and understand what is expected of them in a given situation; leaders must know what to check and when.

The body of these conclusions regarding small unit leader responsibilities, staff planning and supervision, and time management deals with matters that are more often learned by experience rather than in formal training. Nonetheless, there are compelling reasons to seek and find means to raise the level of training in these areas prior to the NTC experience. First, the experience at the NTC itself should prove to be more valuable if incoming units are better prepared in these areas. More importantly, the level of readiness for actual battle should be raised by complementary training protocols which maximize the return from the training experience at the NTC.

We stated at the onset of this chapter that commander, staff officer, and leader performances are the key to the course of events which unfold within an NTC mission segment. Our overall conclusion is that these performances are driven largely by the level of tactical and technical proficiency of these commanders and leaders, and their capability to manage their time effectively in the NTC environment, than they are by the levels of fatigue experienced in that training environment.

APPENDIX B

MINIBATTLE RESULTS AND EXAMPLE IQUEL QUERIES

This appendix is intended to amplify the results presented in the section on Minibattle Results. There we discussed the five minibattles into which the mission segment was partitioned, reported on the various firing events which occurred during each minibattle, and provided an analysis of the detailed results from minibattle 1. On page 33, we stated some summary findings from the quantitative analysis, reserving the comprehensive findings and conclusions for that section on page 40.

The tentative partitioning was accomplished by plotting the paired event data onto a computer generated map of the exercise area. (See figure 6 of the main report.) These data were generated using IQUEL as follows:

```
range of p is PET

range of q is PSIT

retrieve (p.time, p.tpid, p.tx, p.ty, p.result, p.fpid, q.side, p.fx,
p.fy)

where p.flpn = q.lpn

sort by p.time
```

During review of the paired event data output we noticed that fratricides were occurring. These we then identified specifically with the following query:

```
range of p is PET

range of q is PSIT

range of r is PSIT

range of s is PVWT

range of t is PVWT

retrieve (p.time, p.tpid, q.side, s.pveh, p.fpid, p.result, r.side,
          t.ptype)

where p tlpn = q.lpn

and p.flpn = r.lpn

and q.side = s.pside

and r.side = t.pside

sort by p.time
```

The output of this query highlighted the fratricides in any line where q.side = r.side and further identified the target vehicle and firer type.

Confirmation of the minibattle definitions was accomplished by iteration between the battalion AAR and additional IQUEL queries which reported firing events and element locations by minibattle. Toward the end of the process a number of diagnostic queries were made to finalize the minibattle definitions, e.g., the location of <u>unlocated</u> elements or units over the course of the battle. (See example query on Page A-3.)

The initial sets of firing events were obtained by:

```
range of q is FET

range of p is PSIT

range of r is PVWT

retrieve (q.time, q.pid, xl = int4 (q.x), yl = int4(q.y), r.pveh,
          r.pveh, r.pside)

where q.lpn = p.lpn

and p.ptype = r.ptype

and p.side = r.pside

and q.wpn = r.miles

and int4(q.x) > _____ and int4(q.x) < ______

and int4(q.y) > _____ and int4(q.y) < ______

and q.time > "____________"

and q.time < "____________"

sort by q.time
```

We next chose to identify all elements present within the time and space limits of each minibattle re ardless of whether they fired or not. The following IQUEL query was used:

```
range of p is qplt

range of q is psut

retrieve (p.time, p.plpid, xl = int4(p.x), yl = int4(p.y), q.side,
          q.pstat, q.track, q.org)

where p.pllpn = q.lpn

and int4(p.x) > _____ and int4(p.x) < _____

and int4(p.y) > _____ and int4(p.y) < _____
```

```
and p.time > "__________"

and p.time < "__________"

sort by p.plpid
```

This report provided the location and movement traces of all elements present during the minibattle along with any status changes, whether the element was a tracked vehicle or not and identification of the parent unit. We later reformatted this query sorting by p.org to capture movement traces by unit and by side. For example:

```
range of p is gplt

range of q is psut

retrieve (q.org, p.plpid, X1 = int4(p.x), yl = int 4(p.y), q.pstat)

where p.pllpn = q.lpn

and q.side = "B"

and int4(p.x) > _____ and int4(p.x) < _____

and int4(p.y) > _____ and int4(p.y) < _____

and p.time > "__________"

and p.time < "__________"

sort by q.org
```

As mentioned previously, the NTC mission segment data bases contain voids. We generated seventeen IQUEL queries to resolve these kinds of questions. For example, a unit which, according to the plan, should have been positioned into a particular engagement area for one of the minibattles was absent; we found the missing units with the following query:

```
range of p = gplt

range of q = psut

retrieve (p.plpid, q.org, p.time, p.x, q.x, q.pstat)

where p.pllpn = q.lpn

and p.time < "__________"

and p.time > "__________"

and q.org = 1/B/X - 00y/

or  q.org = 2/B/X - 00y/
```

```
or  q.org = 3/B/X - COy/

sort by p.plpid
```

This query located the three platoons of B Company of the participating battalion (designation is here excluded) during the time span in question. This information enabled us to determine precisely when the unit began its movement and to what locations; previous review of the AAR disclosed only that the unit was not deployed according to the original operations order at a time when it effectively could have been.

As presented in the section Minibattle Results, we requested and obtained very valuable assistance from the terrain analysis experts from TRAC-WSMR in our analysis of engagement opportunities. We provided element movement traces to the TRAC-WSMR analysts who applied their terrain analysis models to produce PLOS (probability of line-of-sight), inview and out-of-view segment lengths, and first and expected opening range data for each of our minibattles.

When providing us the results of this work the TRAC-WSMR analysts expressed some concerns with respect to small sample sizes in respect to four of the five minibattles. Minibattle 1 contains ample data, and we were informed that the terrain statistics delivered could be taken as representative and accurate for that minibattle. Fortunately, that was the central minibattle in the mission segment we investigated, and is the one we included in the main body of the report. All five of the minibattles analyzed are summarized in this appendix.

The distribution of first and expected opening ranges presented in the appendix come directly from the TRAC-WSMR terrain and engagement opportunity analysis. The NTC engagement range statistics and distributions come from the paired event data using the following IQUEL query:

```
range of p is PET

range of q is PSIT

retrieve (np.time, p.fpid, p.result, q.ptype, range = sqrt
        (int4(p.tx) - int4(p.fx))**2 + (int4(p.ty) int4(p.fy))**2)

where p.flpn = q.lpn

and int4(p.fx) > _____ and int4(p.fx) < _____

and int4(p.fy) > _____ and int4(p.fy) < _____

and p.time > "__________"

and p.time < "__________"

sort by q.ptype
```

<u>Minibattle 1</u>: The probability of line-of-sight for minibattle 1 is shown in figure B-1. When coupled with the inview segment length data in figure B-2 it can be readily seen that the assigned A Company defensive position

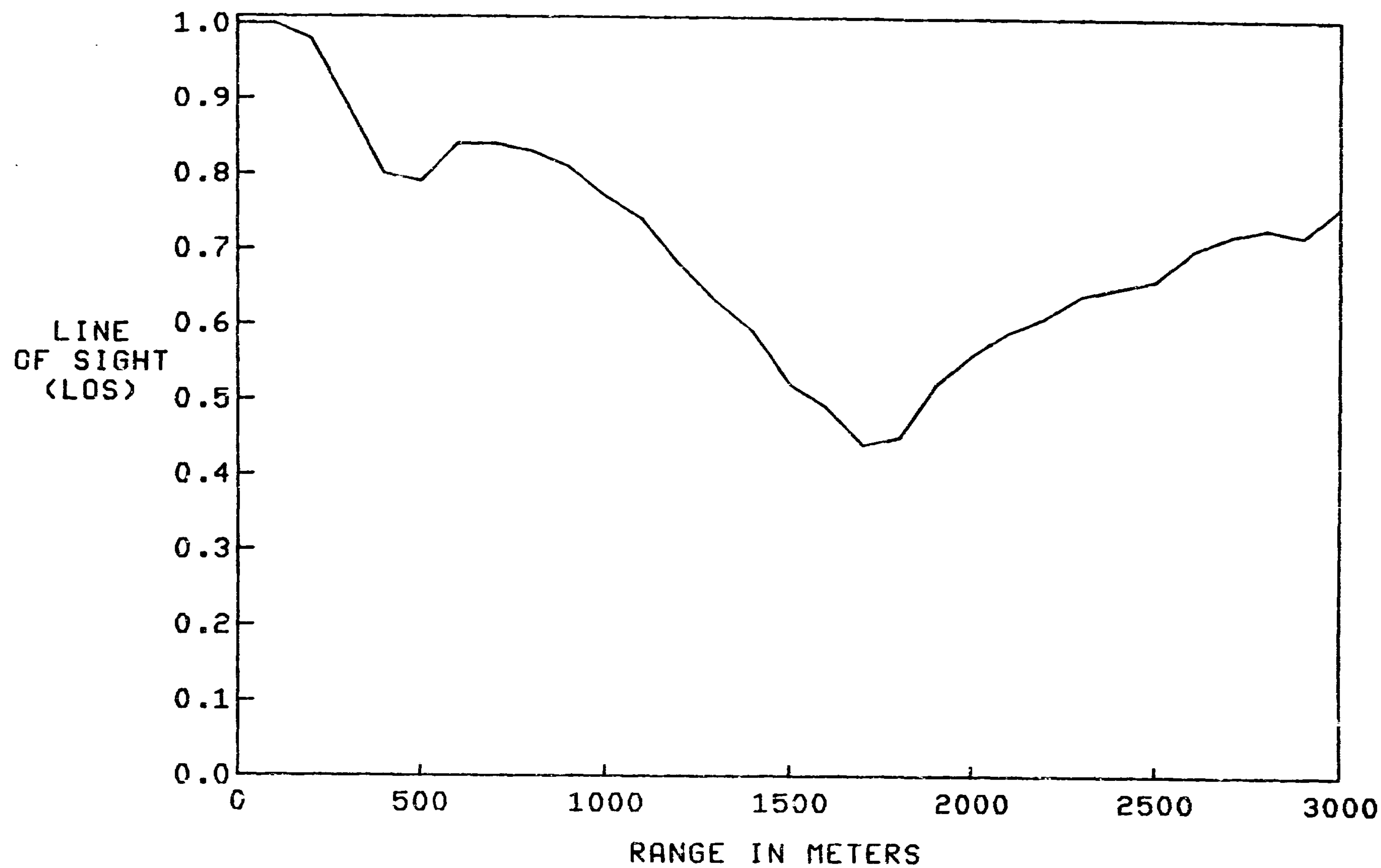


FIGURE B-1. BLUFOR PROBABILITY OF LOS -- MINI-BATTLE 1

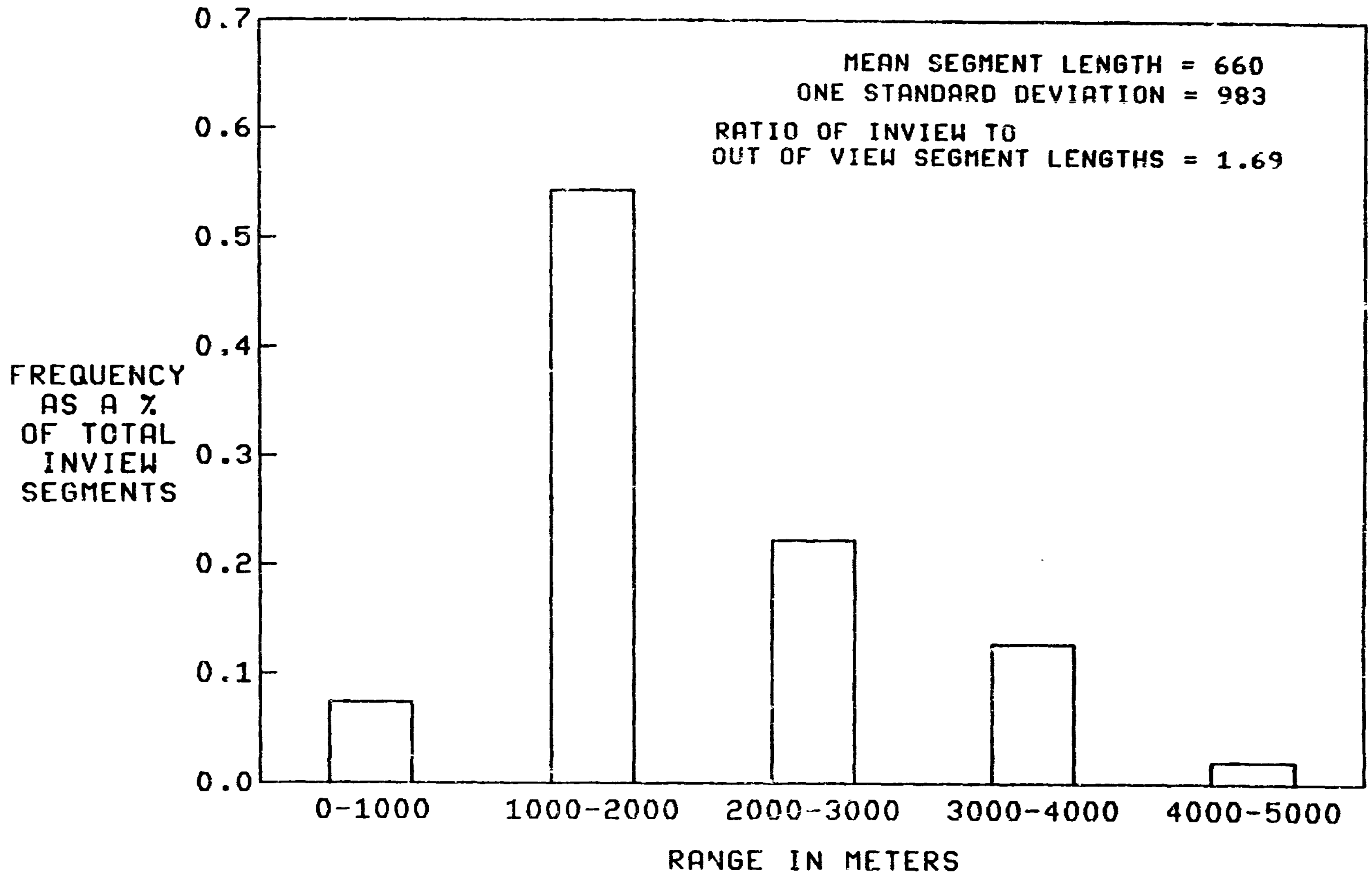


FIGURE B-2. DISTRIBUTION OF INVIEW SEGMENTS -- MINI-BATTLE 1 afforded excellent engagement opportunities against a force attacking north toward hills 751 and 758 from positions west of Bone. These line-of-sight and inview segment length data are empirical data actually calculated on an element-by-element basis from the position and movement data provided. Excellent line-of-sight conditions prevail well beyond three thousand meters. Ample defensive positions for a full company of tanks existed here. The mean inview segment lengths and the associated distribution reflect that many long segment lengths exist, which would not only afford manifold engagement opportunities for tanks but also for ITV.

It will simply be noted here that no ITV within the battalion task force were positioned with A Company. In fact, all 12 ITV were positioned to the rear on the forward slopes of hill 720. This point was amplified on further in the section on Qualitative Analysis. The point here is that ample engagement opportunities would have been presented had some ITV been positioned forward with A Company. The ratio of inview to out-of-view segment lengths reflects that the mean out-of-view segment lengths were in fact of much shorter duration than the inview segment lengths. The desirability of A Company's assigned battle position as a defensive position is further emphasized in figure B-3 where we have presented the distributions of first and expected engagement ranges from the TRAC-WSMR analysis along with the actual distribution of tank engagements from minibattle 1 at the NTC. Although only five BLUFOR tanks actually fired during this minibattle, the performance of these crews reflects a high level of crew proficiency in target acquisition and engagement. In the 1000-2000 and 2000-3000 meter range bands engagement performance met the expected opening range predictions from TRAC-WSMR. As the TRAC-WSMR analysis considers only terrain effects and not acquisition and effective range capabilities the lower NTC performance at the extended range should not be a cause for concern. The higher actual percent of engagements at the 0-1000 range band probably reflects an acceptable shift in the actual versus expected engagement range distributions due to actual acquisition capabilities. The data support the statement that the tank crews which did fire in minibattle 1 performed well. The lack of mission success resulted from small unit leadership shortcomings in the positioning of the tanks and in the preparation of an adequate direct fire plan and follow-on supervision by small unit leaders.

Minibattle 1A: The probability of line-of-sight data reflects a shooting gallery effect out to seven hundred meters; then again between 2100 and 2600 meters the OPFOR is nearly always in view from BLUFOR. Figures B-4 and B-5 reflect these intervisibility conditions. What actually occurred here is that a few elements of A Company were engaging the OPFOR, who had bypassed them, into their rear as long as they were able in the close-in intervisibility window. This is further reflected in figure B-6 which reflects that all the BLUFOR firings occurred in the near engagement window. As shown in figure B-7, only ten firings, all from BLUFOR, took place during this minibattle.

Minibattle 2: The PLOS data shown in figure B-8 and the inview segment length data shown in figure B-9 reflect excellent intervisibility in the 1000 - 2000 meter range band. The OPFOR was at the time attempting to accelerate his advance and apparently paid little heed to the counterattack by A Company. Just three tanks from A Company were briefly engaged with 15 T-72 and 20 BMP from the OPFOR. Yet from a locally engaged force ratio of

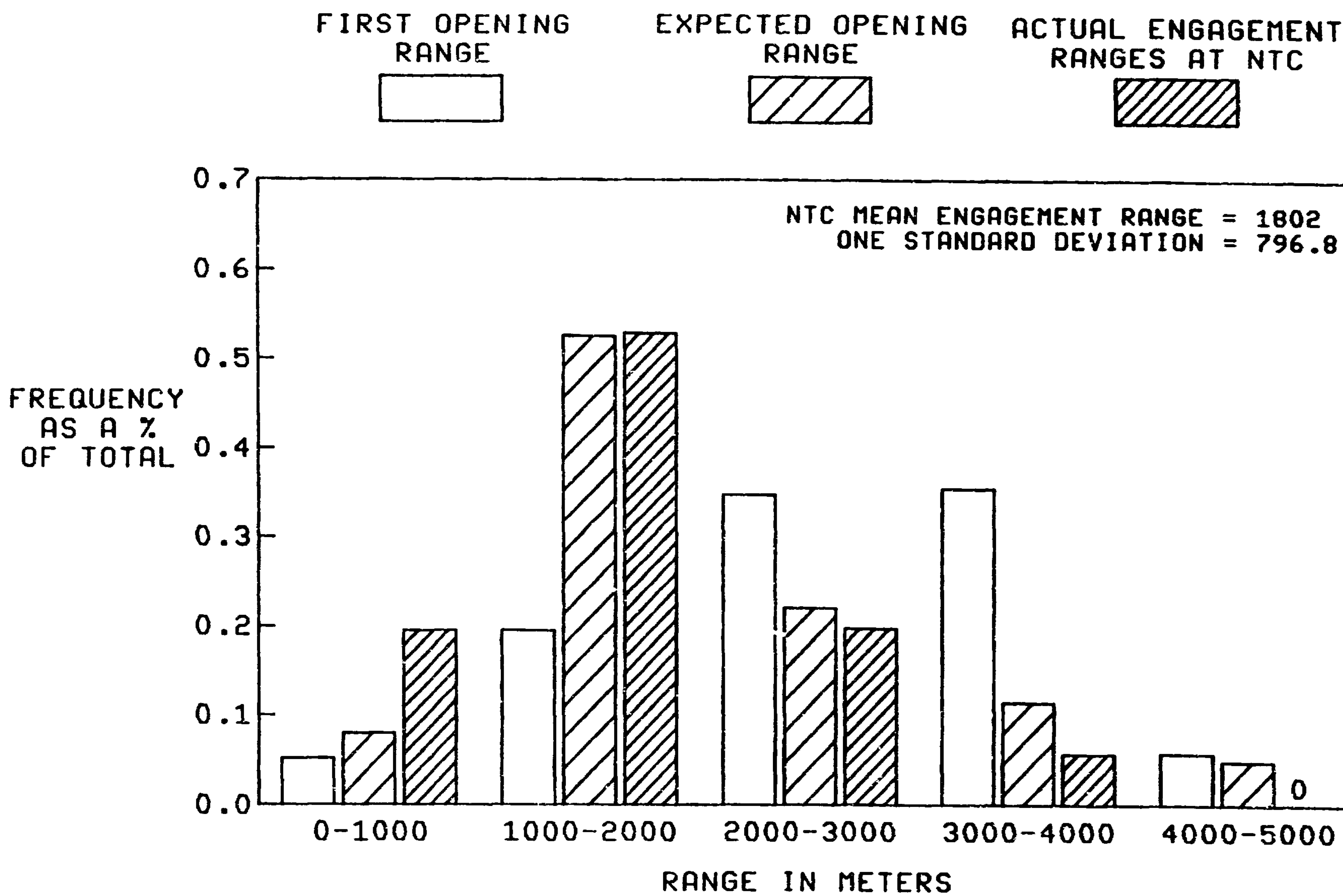


FIGURE B-3. DISTRIBUTION OF FIRST AND EXPECTED OPENING RANGES AND ACTUAL TANK ENGAGEMENT RANGES AT THE NTC -- MINI-BATTLE 1

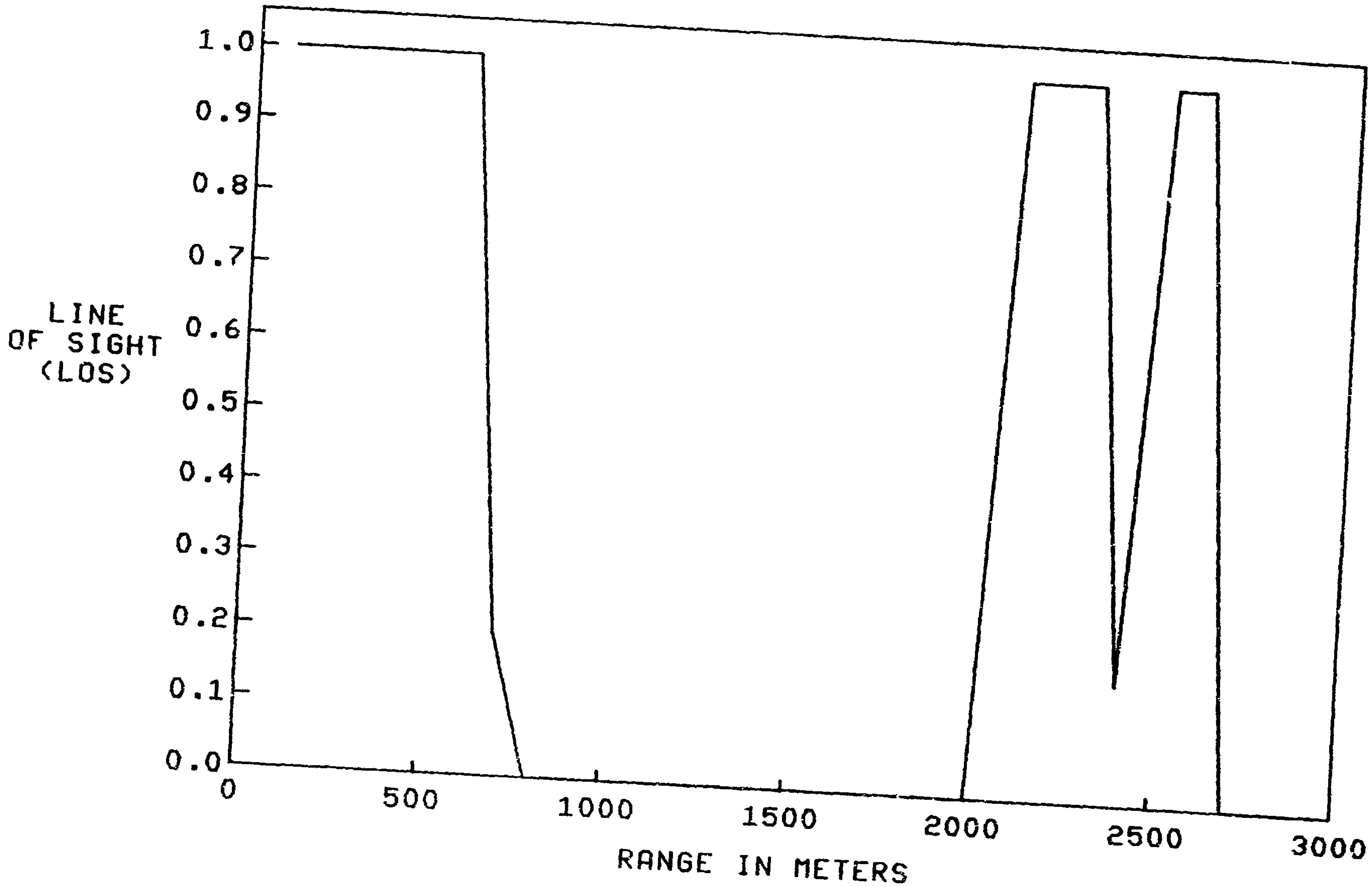


FIGURE B-4. BLUFOR PROBABILITY OF LOS -- MINI-BATTLE 1A

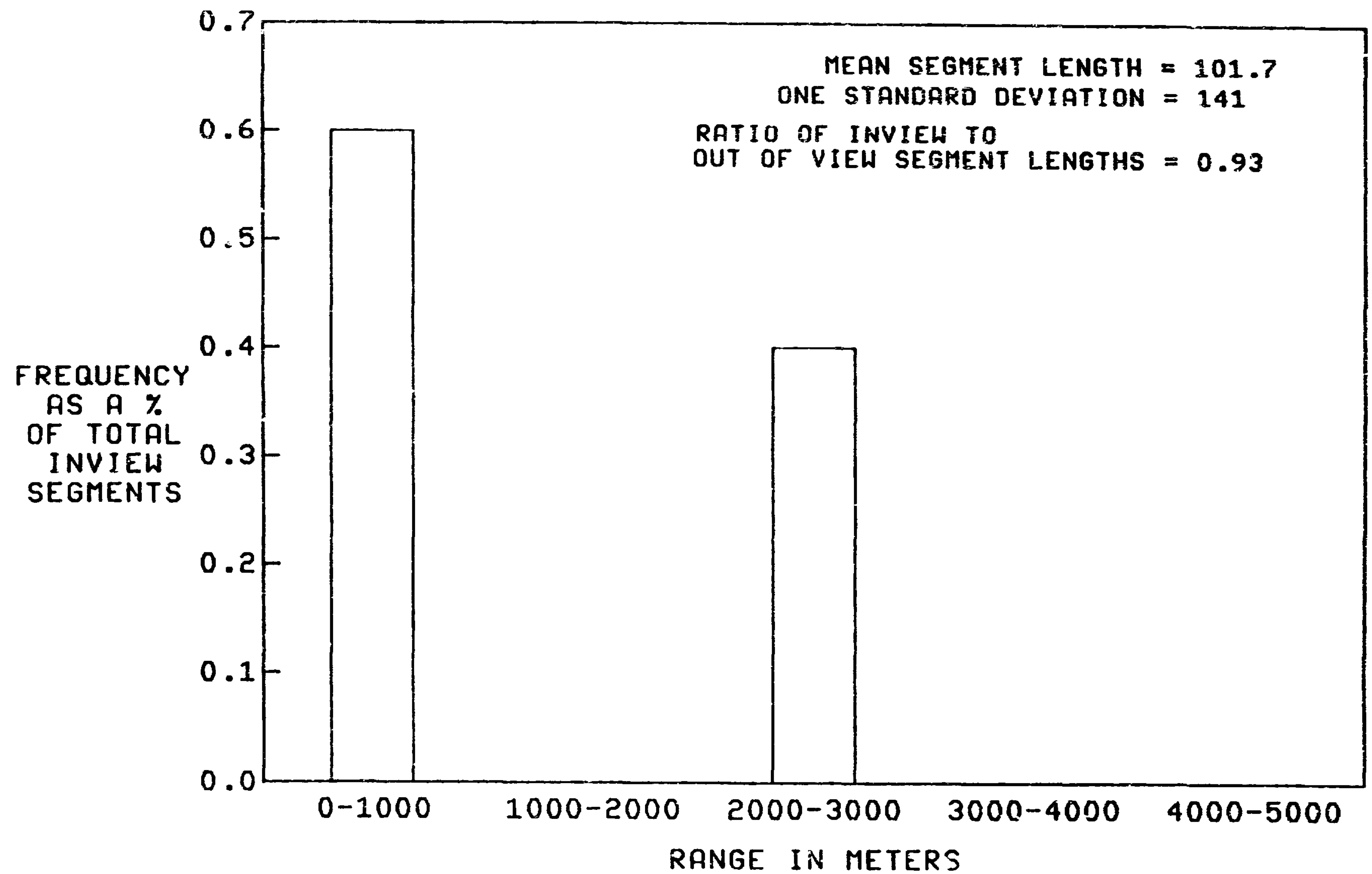


FIGURE B-5. DISTRIBUTION OF INVIEW SEGMENTS -- MINI-BATTLE 1A

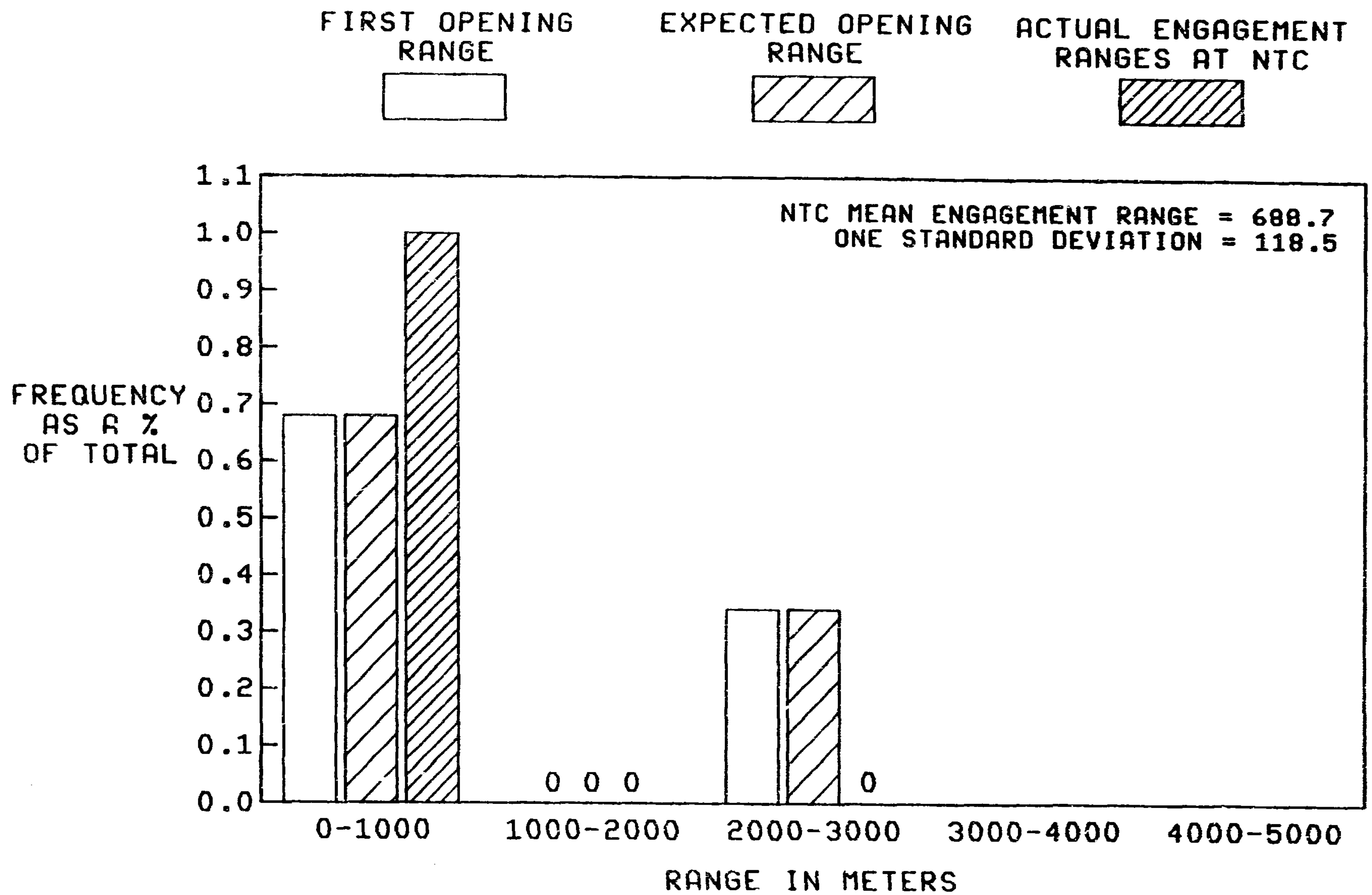


FIGURE B-6. DISTRIBUTION OF FIRST AND EXPECTED OPENING RANGES AND ACTUAL TANK ENGAGEMENT RANGES AT THE NTC -- MINI-BATTLE 1A

	MINIBATTLE					TOTALS
	1	1A	2	3A	3B	
BLUFOR:						
PAIRED FIRINGS	17	3**	8	10	2	40
PAIRED KILLS OF T-72	0	0	2	2	2	6
PAIRED KILLS OF BMP	3	1	1	3	0	8
PAIRED HITS/NO KILL OF T-72	1	1	0	0	0	2
PAIRED HITS/NO KILL OF BMP	4	0	0	1	0	5
ALL FIRINGS	70	10**	39	31	23	173
OPFOR:						
PAIRED FIRINGS	2*	0	5*	2	6*	15*
PAIRED KILLS OF M-60	0	0	0	0	2	2
PAIRED KILLS OF BFV	0	0	2	0	0	2
PAIRED HITS/NO KILL OF M-60	0	0	0	0	0	0
PAIRED HITS/NO KILL OF BFV	0	0	1	0	0	1
ALL FIRINGS	175	0	84	38	19	316

*Excludes attempted fratricides.
**Engagements by Bypassed BLUFOR elements into OPFOR's rear.

FIGURE B-7. TABLE OF FIRING EVENTS BY MINI-BATTLE

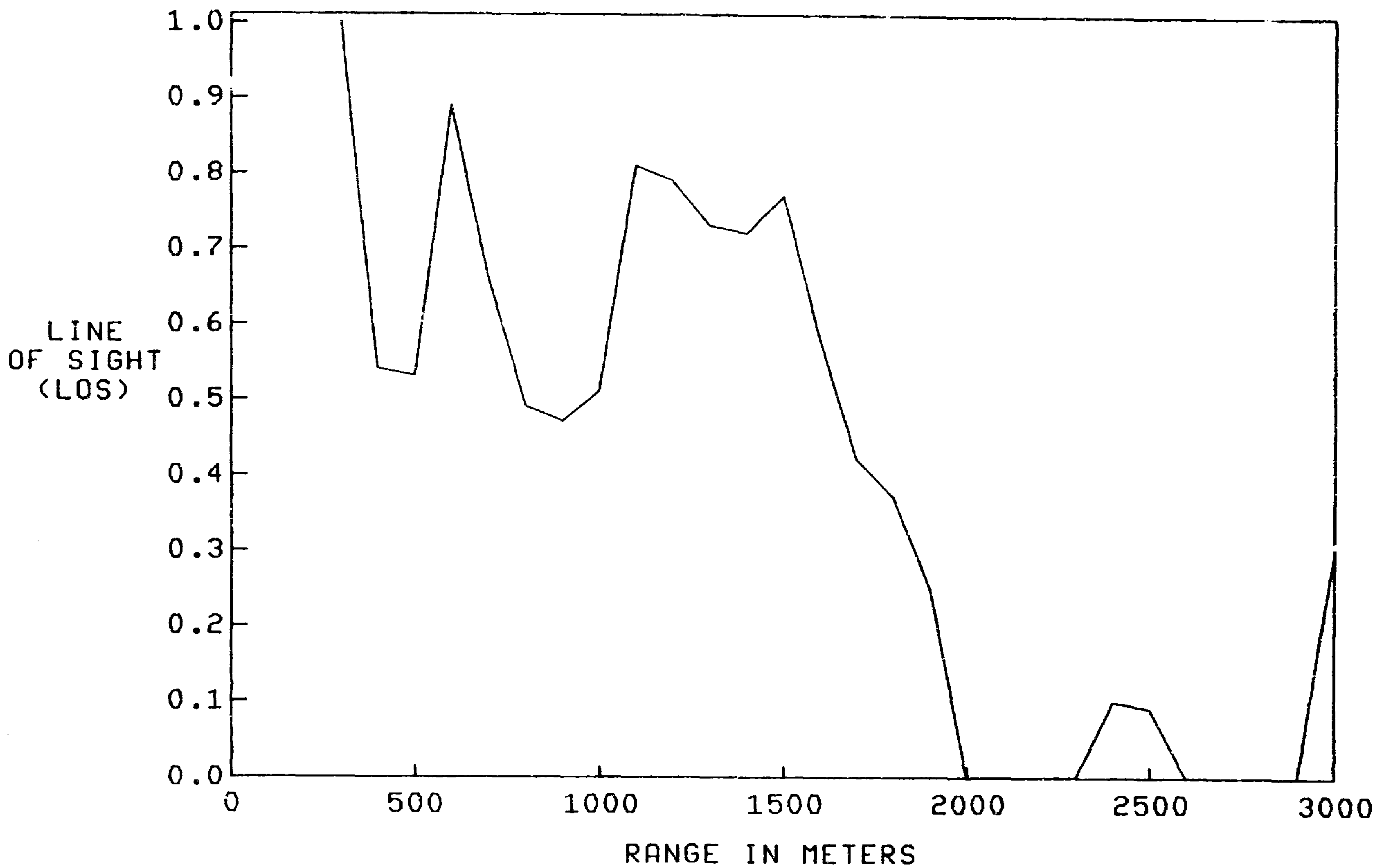


FIGURE B-8. BLUFOR PROBABILITY OF LOS -- MINI-BATTLE 2

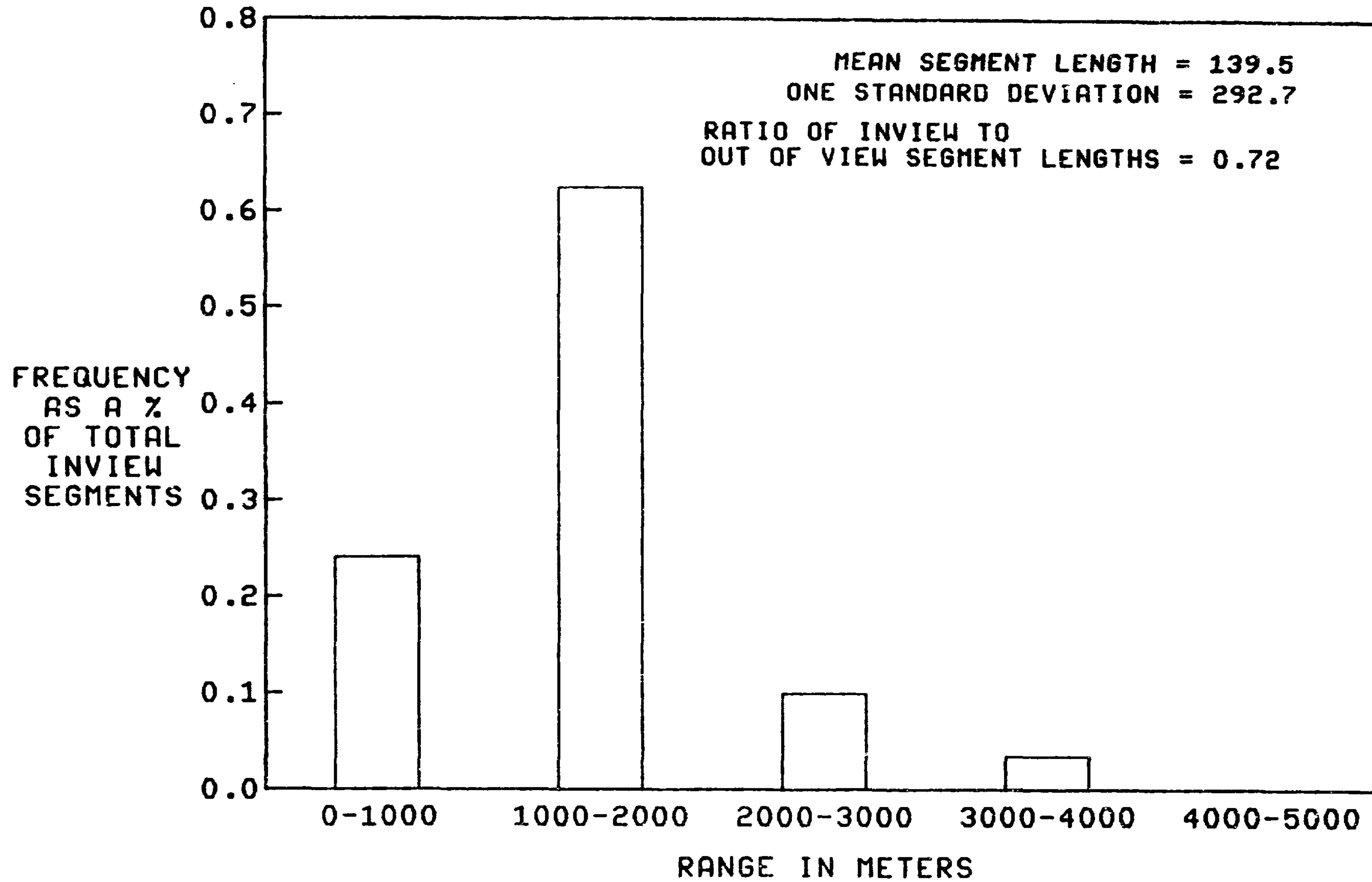


FIGURE B-9. DISTRIBUTION OF INVIEW SEGMENTS -- MINI-BATTLE 2

3/35 or .09 a remarkable shot ratio of 39/84 or .46 was achieved by the few BLUFOR elements. It is readily apparent from the engagement range distribution data in figure B-10 that the BLUFOR elements took on a rapidly advancing OPFOR; they inflicted some attrition of the OPFOR in even the sparse paired event data, but did not slow his advance at all.

Minibattle 3A: This is the last battle of any consequence prior to the OPFOR's final assault on Hill 720, although the smaller minibattle 3B was taking place concurrently about three kilometers to the southeast. Intervisibility conditions, as reflected in figures B-11 and B-12, were good out to 2000 meters. At this juncture in the mission segment, the OPFOR was clearly in exploitation having effected a breakthrough and was rapidly advancing toward his assigned objective. We estimate from the ground player location table that the OPFOR outnumbered BLUFOR 16 to 3 or 5.33:1. Thus, he was able to outshoot the small defending BLUFOR force with the engagements occurring at ranges well short of what the terrain would have allowed as reflected in figure B-13. At this point in the battle, the OPFOR could sustain a few more casualties in order to maintain the momentum of his attack.

Minibattle 3B: This companion minibattle to 3A also involved a small number of elements with the OPFOR enjoying a 4:1 locally engaged force ratio. Out to 1700 meters the opposing elements were in continuous view of one another as shown in figures B-14 and B-15. The BLUFOR held a slight edge in the number of shots fired, but again, the OPFOR in exploitation was able to maintain the momentum of his attack. Those engagements which did occur took place at very close range as reflected in figure B-16.

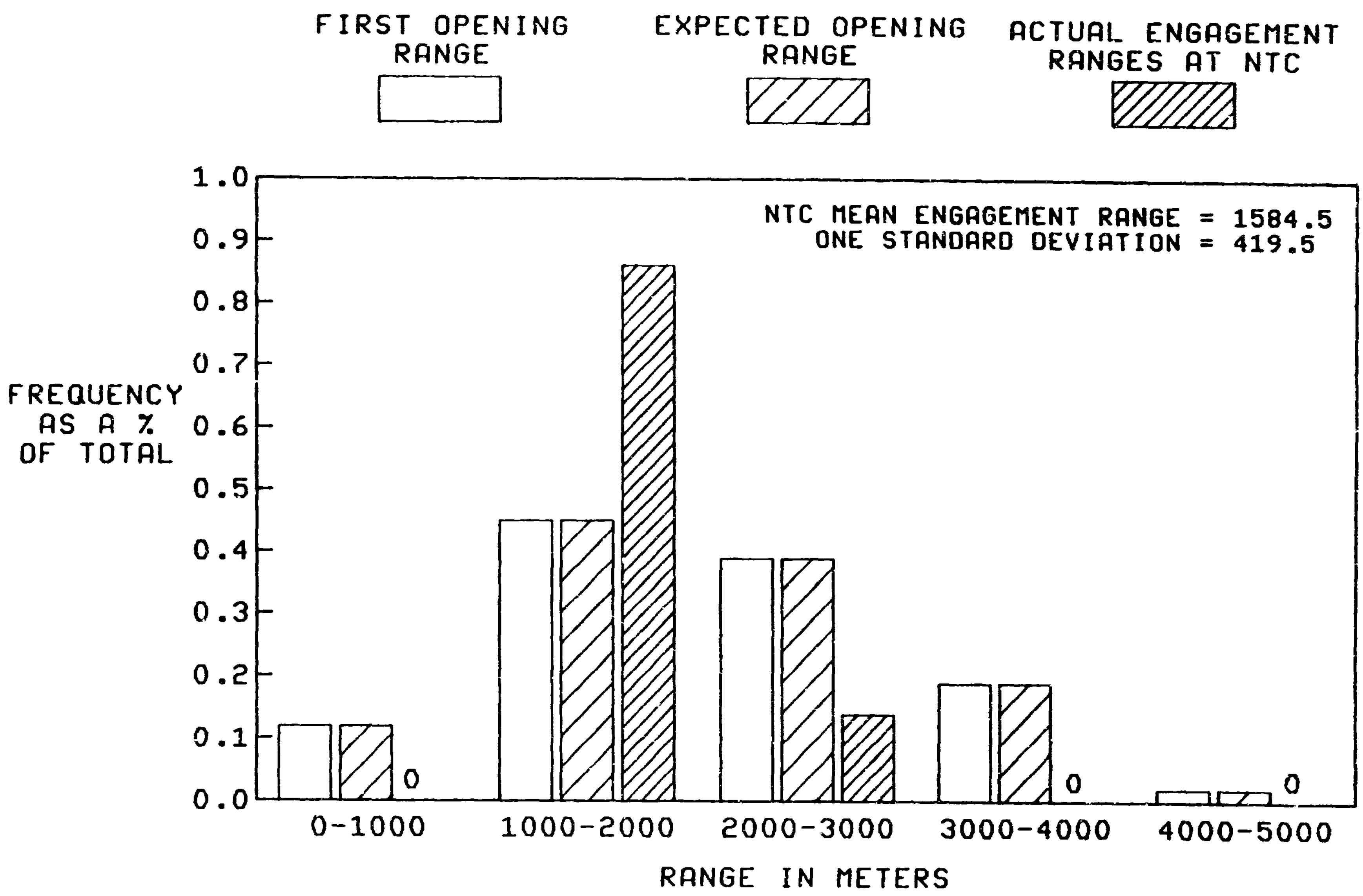


FIGURE B-10. DISTRIBUTION OF FIRST AND EXPECTED OPENING RANGES AND ACTUAL TANK ENGAGEMENT RANGES AT THE NTC -- MINI-BATTLE 2

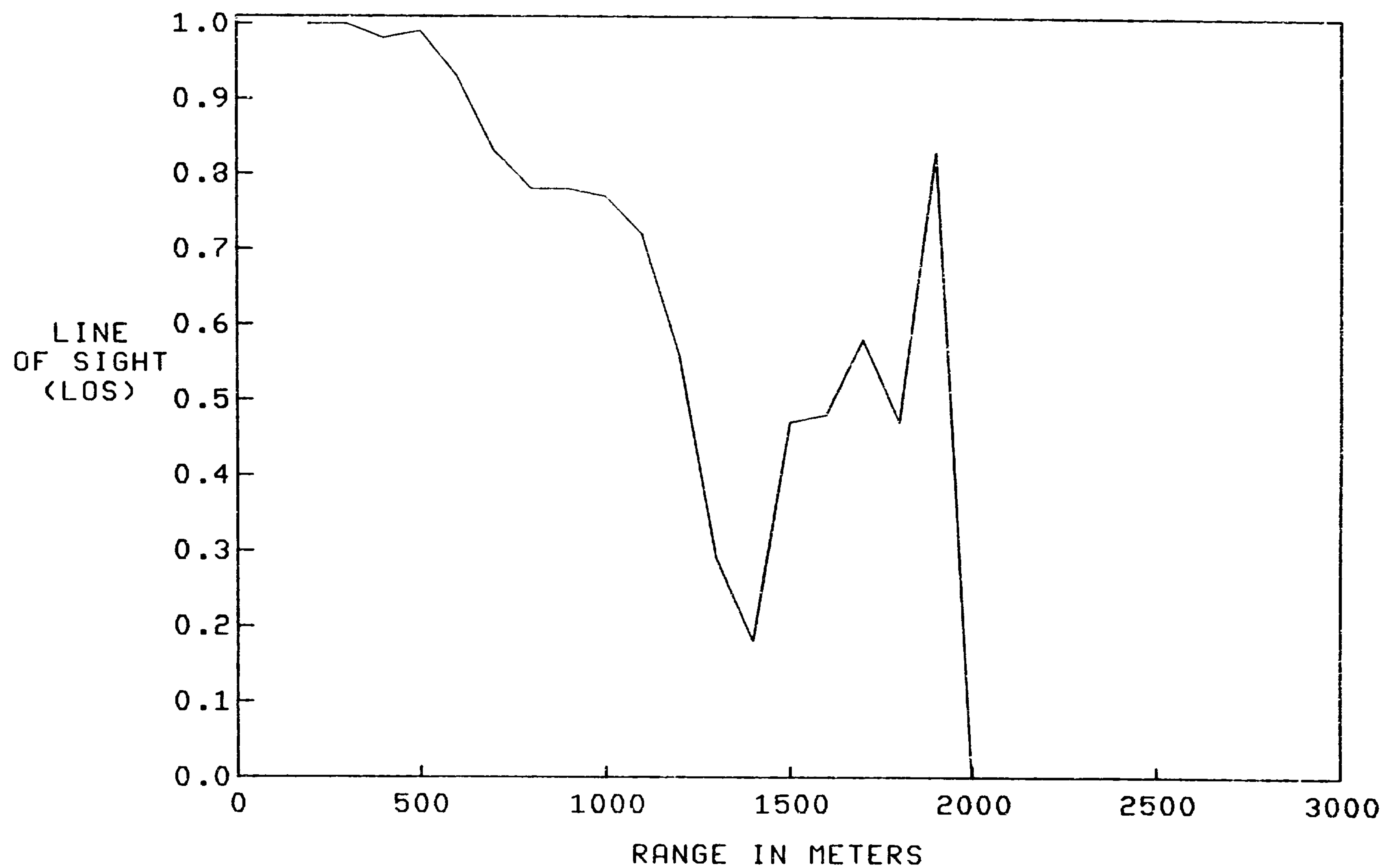


FIGURE B-11. BLUFOR PROBABILITY OF LOS -- MINI-BATTLE 3A

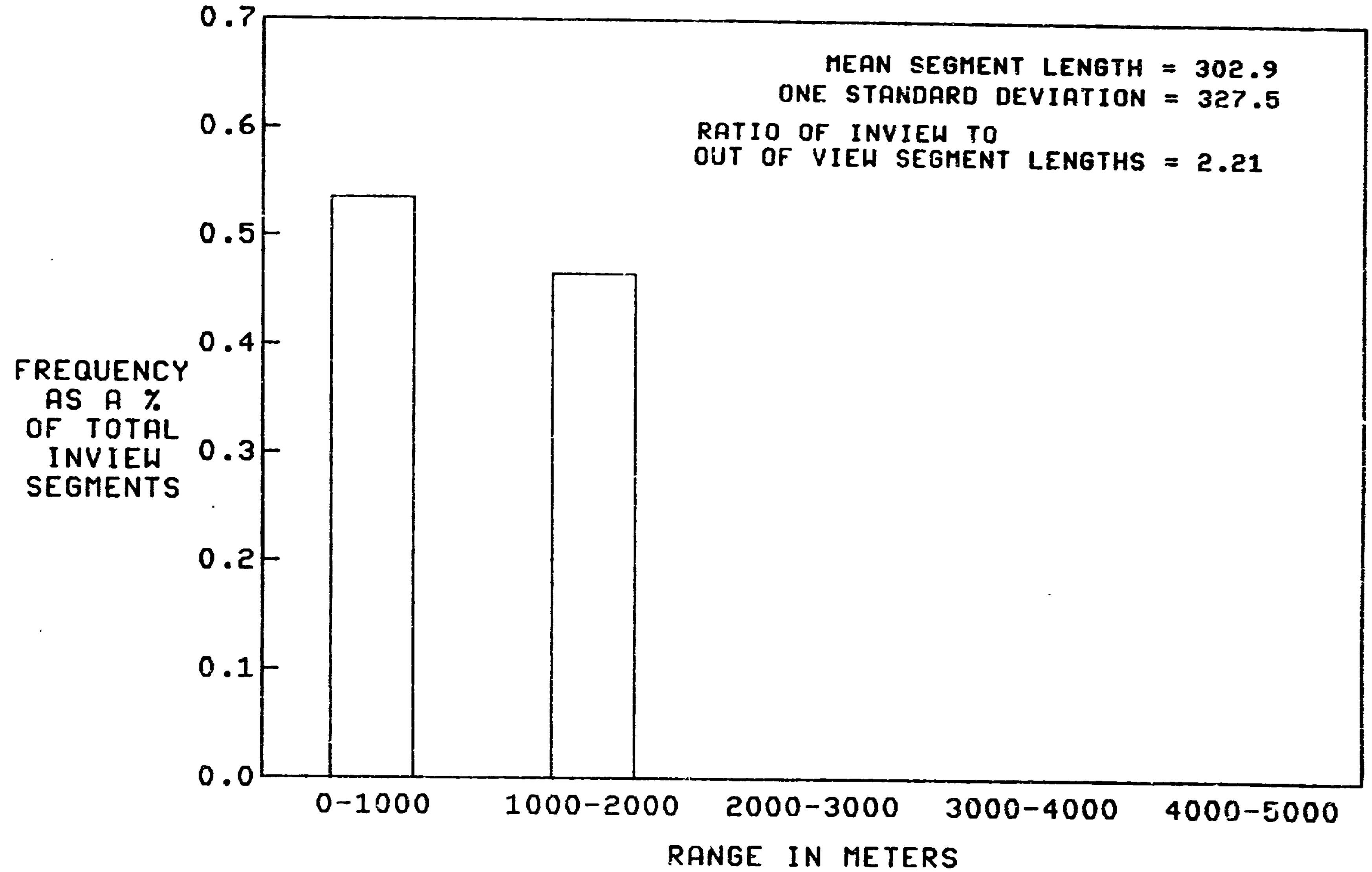


FIGURE B-12. DISTRIBUTION OF INVIEW SEGMENTS -- MINI-BATTLE 3A

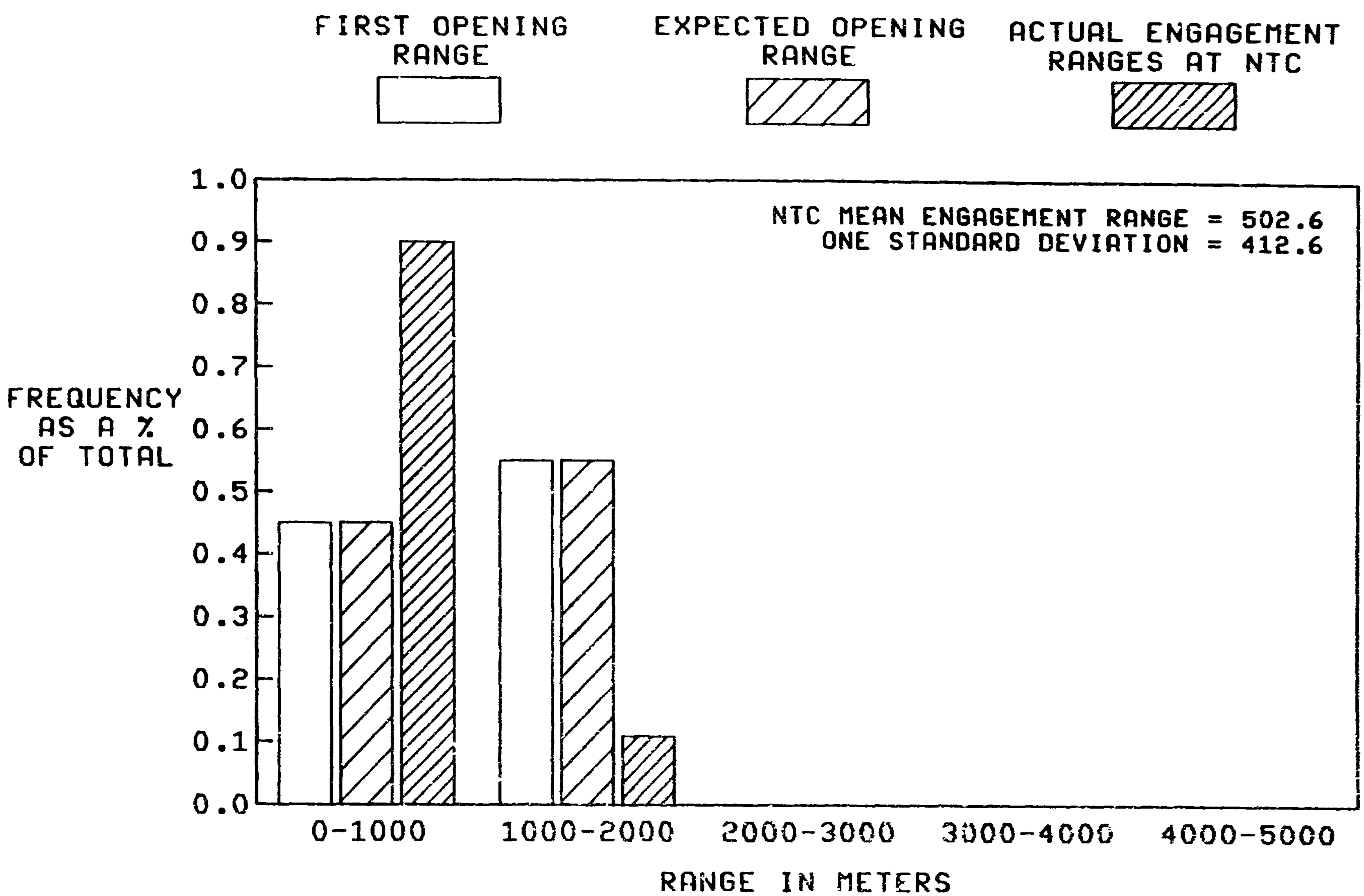


FIGURE B-13. DISTRIBUTION OF FIRST AND EXPECTED OPENING RANGES AND ACTUAL TANK ENGAGEMENT RANGES AT THE NTC -- MINI-BATTLE 3A

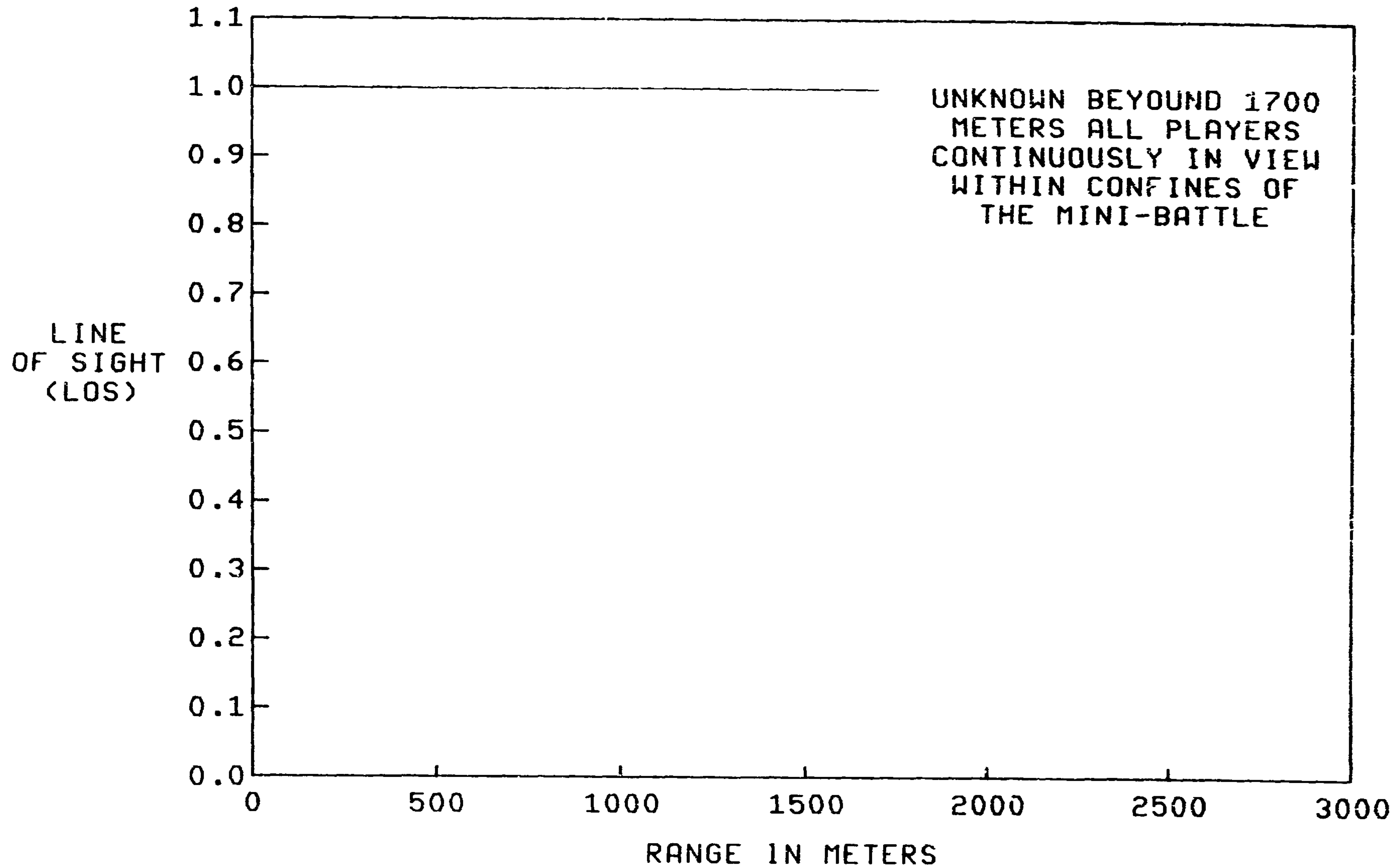


FIGURE B-14. BLUFCR PROBABILITY OF LOS -- MINI-BATTLE 3B

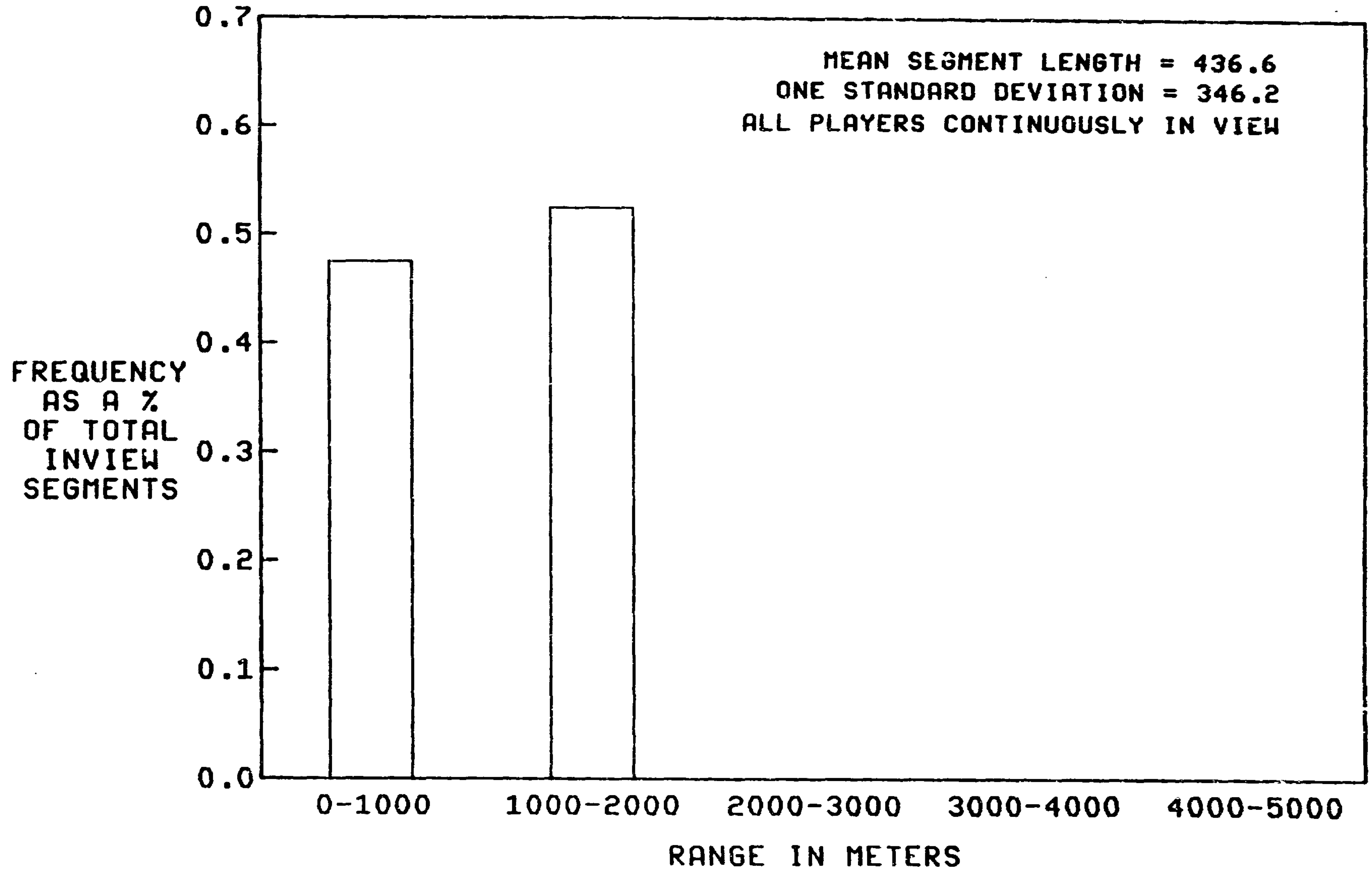


FIGURE B-15. DISTRIBUTION OF INVIEW SEGMENTS -- MINI-BATTLE 3B

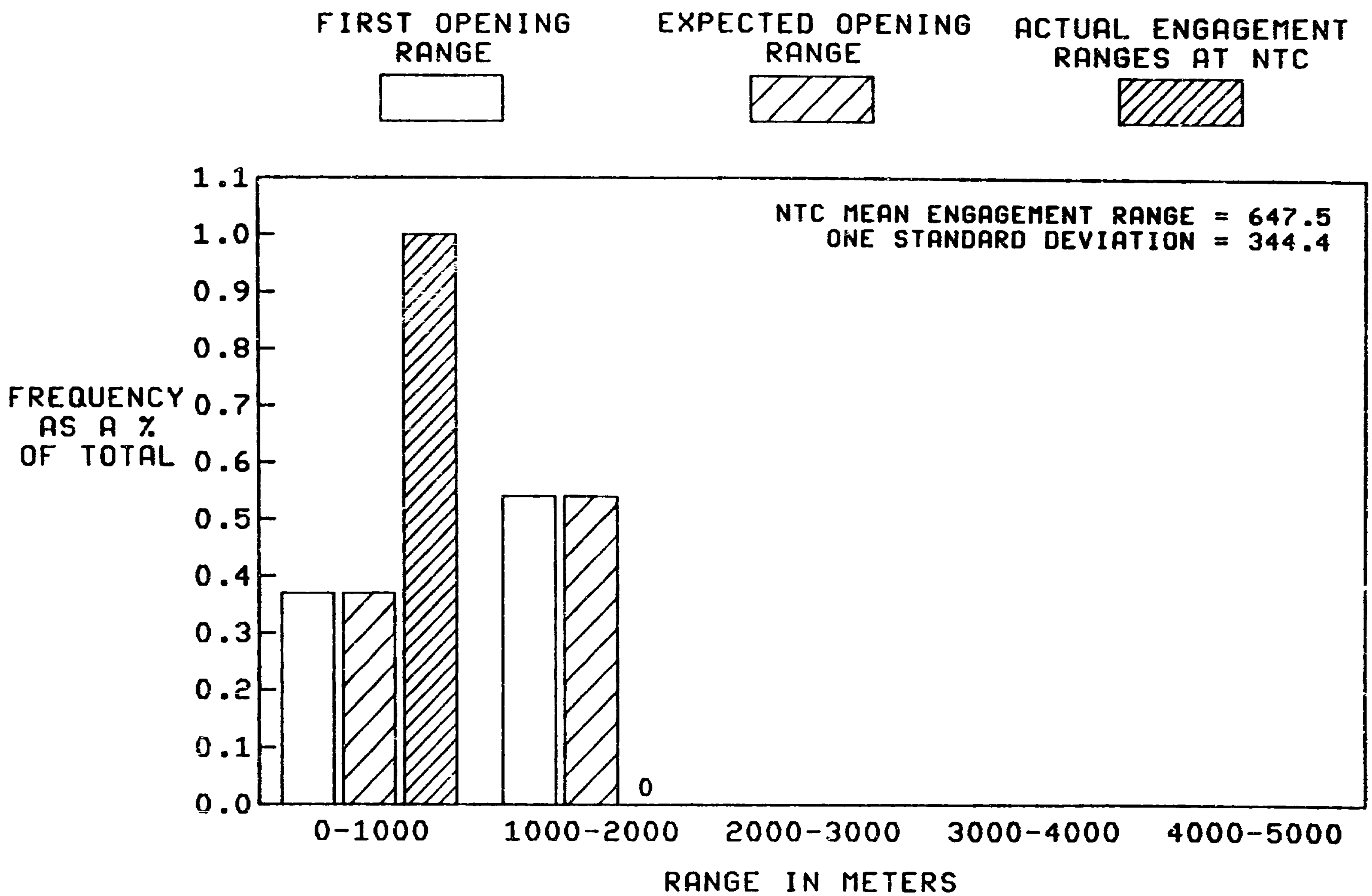


FIGURE B-16. DISTRIBUTION OF FIRST AND EXPECTED OPENING RANGES AND ACTUAL TANK ENGAGEMENT RANGES AT THE NTC -- MINI-BATTLE 3B

APPENDIX C

FOLLOW-ON CONSIDERATION OF ADDITIONAL AFTER ACTION REVIEWS (AARs)

Because in the rotation examined we depended heavily on the battalion task force after action review (AAR) to both supplement and complement the quantitative analysis, we elected to review four additional AARs of similar mission segments from other rotations, chosen at random, to determine if the mission segment analyzed was alike or not in its conduct and results to comparable mission segments from other rotations. This appendix contains a summary of those follow-on reviews as compared with the review accomplished earlier and reported in the Qualitative Analysis Results section of the main report. We came to the conclusion that the AAR from reflected a mission segment that in its conduct and results was similar to the other four in most important aspects. This appendix is formatted according to the AAR taxonomy stated in the Method of Approach section of the main report.

Commander and Battalion S-3. The focus here is on the commander's and operations officer's planning and supervision during the planning, preparation, and execution phases of the mission segment. Key areas in planning include Commander, S-3, FSO, and Engineer involvement with the S-2 in the IPB, to insure its completeness and correct uses in:

- determining the concept of operations;
- planning the counter-reconnaisance operation;
- selecting of battle positions and engagement areas;
- planning of indirect fires;
- obstacle and position preparation planning; and
- preparing and disseminating a complete and easily understood operations order.

In preparation the focus is on:

- preparing positions;
- implementing the obstacle and barrier plan;
- rehearsing repositioning and counterattack plans;
- detailed fire planning for both direct and indirect fires, insuring that these plans are reflective of the IPB, tied into the planned obstacles and barriers and responsive to the concept of operations; and
- insuring that combat service support plans and means are adequate to support all phases and contingencies related to the concept of operations.

In execution, the focus is on:

- "seeing the battlefield" through prior IPB and ISTA means insuring essential and timely reports on the developing situation;

- effecting synchronization of all combat means during conduct of the battle; and

- responding via fragmentary orders and supervision to the developing situation via the repositioning of maneuver elements and the reallocation of combat support when needed according to the concept of operation.

Use is made of the foregoing taxonomy in figure C-1 to summarize the results of our review of the five mission segments considered. Because of the overall responsibilities of the Commander and the wide ranging coordination responsibilities of the Battalion S-3, areas are included in this particular comparison which will reappear subsequently regarding other commanders, leaders, and staff officers, e.g., adequacy of the IPB, and thorough and coordinated obstacle planning. As reflected in figure C-1 there were nine areas which predominated, i.e, there were either three or four occurrences, from the four mission segments reviewed, in which the observer-controllers specifically critiqued a particular area during the AARs. In all nine areas the rotation was also critiqued. So, while there is not mirror-like comparability among these five mission segments, in those areas dealing with the tasks or functions most frequently critiqued, there exists a very high level of consistency.

Fire Support Officer and Mortar Platoon Leader. Here the focus of our review was on the adequacy of fire planning including its relationships to the IPB and the commander's concept of operation. Among the four added mission segments reviewed, we identified five areas that were critiqued in two or three of the mission segments. These five areas and the number of critique observations were:

- final protective fires not planned for all company team battle positions -- 3;

- all planned fires were not entered into TACFIRE -- 2;

- mortars were positioned out of effective range -- 2;

- fires were not planned in support of the main engagement area -- 2; and

- fires were not planned forward of obstacles -- 2.

As reported in the section, Fire Support, fire planning and execution were generally well done. The principal shortfall was the lack of adequate fire planning in the task force's rear around E Company's position. Thus in only one of the five areas did we find comparability; however, that did occur in the area critiqued most frequently in the other four mission segment AARs.

Function / Position	Planning	Preparation	Execution
BASE	inadequate IPB sound defensive concept inadequate direct fire planning good indirect fire planning inadequate obstacle planning incomplete operations order	battle positions well located lack of adequate rehearsals for repositioning inadequate detailed fire planning and tie-in with obstacle plan inadequate supervision of preparations incomplete barrier implementation	ineffective counter-reconnaisance ineffective tracking of OPFOR inadequate repositioning of maneuver forces partially effective indirect fire defeated in detail overall lack of synchronization poor reporting
4 OTHERS	sound IPB - 1 sound defensive concept - 1 inadequate planning of direct fires - 3 inadequate planning of indirect fires - 2 inadequate obstacle planning - 3 complete operations order - 1	battle positions not well located with respect to engagement areas - 2 lack of adequate rehearsals for repositioning - 4 inadequate detailed fire planning and tie-in with obstacle plan - 4 inadequate supervision of preparations - 3 incomplete barrier implementation - 4	ineffective counter-reconnaisance - 3 effective tracking of OPFOR - 1 timely and sound repositioning - 1 effective use of indirect fire - 2 defeated in detail - 2 overall lack of synchronization - 3 poor reporting - 3

FIGURE C-1. COMMANDER AND BATTALION S-3 PERFORMANCE

Battalion S-3 Air and Air Liaison Officer. In neither the AARs or the take home packages (THPs) for the four added mission segments are many critiques made regarding these two individuals. The same pertained to the rotation. We have judged this apparent comparability to have little meaning. It is more likely a reflection of the low levels of attack helicopter and close air support employments in the five mission segments considered.

Battalion S-2. Clearly, the IBP is an area of substantial emphasis at the National Training Center. As a consequence, the S-2's activities are taken under close scrutiny and the AARs deal in depth with S-2 planning, effectiveness of coordination and dissemination, and tracking of the OPFOR during the conduct of a mission segment. The most frequent areas critiqued in the four added AARs reviewed were:

- insufficient or poorly placed NAIs (named areas of interest) or TAIs (target areas of interest) -- 3;
- insufficient DST (decision support template) -- 3;
- poor reporting -- 3;
- poor tracking of the OPFOR -- 3;
- all mobility corridors or avenues of approach not identified -- 2; and
- poor counter-reconnaisance planning -- 1.

During the mission segment, all six of these areas were identified as being poorly or incompletely done; so here, too, we found a very high level of consistency among the five mission segments.

Scout and Surveillance Platoon Leaders. The single predominant area of critique in the four added AARs dealt with the inadequacy of planning for and effecting good command and control during the counterreconnaisance operation. This is not surprising; C^2 of a counterreconnaisance is a severe challenge to units operating over a wide front in the pace of an OPFOR undertaking reconnaisance operations, largely under the cover of darkness, in preparation for an attack. It is nonetheless essential to establish and maintain effective C^2 if the platoon's two important functions of counter-reconnaisance and development of an accurate picture of the OPFOR situation are to be accomplished. In mission segment neither of these functions was adequately accomplished, due in large measure to ineffective C^2.

Air Defense Platoon Leader. Among the four added mission segments, there were three areas where in two of the four mission segments similar critiques were made during the AARs. These three area were:

- poor command and control (C^2);
- poor communications with the forward alerting aircraft radar (FARR) and the direct early warning system (DEWS); and
- poor understanding of the concept of operations.

In the mission segment five specific critiques were made during the AAR, all having to do in one way or another with the lack of effective C^2 in the air defense platoon.

Engineer Company Commander. In the four added mission segment AARs, seven areas were critiqued with the frequencies indicated below:

- obstacles poorly sited -- 4;
- obstacles not covered by direct fire -- 4;
- engineer did not participate in the battalion task force planning -- 3;
- poor or insufficient fighting position preparation -- 3;
- small fraction of the planned obstacles actually installed -- 3;
- occurrence of mine fratricides -- 2; and
- poor FASCAM planning -- 1.

All seven of these areas were the subject of critique during the AAR.

Battalion XO, Battalion S-4, Battalion S-1, and Support Platoon Leader. The two most frequent areas of critique in the four added AARs were the S-4's and support platoon leader's failures to manage effective supply distribution and the failures on the part of the company teams to make their combat servce support needs known. Both these were mentioned as areas needing improvement during the AAR.

Company Team Commanders and their Platoon Leaders. The seven areas most frequently critiqued during the AARs at the company team and lower levels along with their frequencies of occurrence for the four add on mission segments are reflected below:

- planning for and rehearsal of unit repositioning plans lacking or inadequate -- 4;
- lack of or poor coordination with the engineers regarding obstacle and barrier planning and implementation -- 4;
- poor execution of repositioning plans -- 3;
- incomplete direct fire planning -- 3;
- poor reporting on current situations and activities -- 3;
- poor position preparation -- 2; and
- poor indirect fire planning -- 2.

Without exception during the conduct of the mission segment, these seven areas were similarly critiqued and, in all but one area, more than once among all the task force's company teams.

In summary, though only four additional battalion level AARs were reviewed, we found among them a high level of consistency, not only within themselves, but also with the mission segment. Thus, we feel comfortable with the contribution the qualitative analysis made to our overall analyses, having found, through the process reported in this appendix, that the AAR is highly consistent with four other battalion task force AARs chosen at random.

APPENDIX D

ANALYSIS OF WRIST MONITOR DATA

The literature review leading to the refinement of the causal model disclosed several findings. There is evidence of operationally significant performance degradation after 36-48 hours if work is more or less continuous. Performance on simulated combat tasks showed marked performance decrements after 48 hours without sleep. There are wide individual differences in the amount of sleep required each night, ranging from 3.5 hours to as much as 10-12 hours. Chronic restriction of sleep length to less than 4.5 hours per night is not possible without performance impact. Cognitive abilities are the weak link in human performance for continuous operations. Given the situation that leaders usually obtain the least amount of sleep and perform the most cognitively demanding tasks, the likelihood of catastrophic failure is greatly increased for unit performance.

HTI proposed the research plan for examining the effects of sleep loss on leadership and unit performance at the NTC. The Army Research Institute (ARI) with the Center for Army Leadership (CAL) and the Center for Army Lessons Learned (CALL) has a continuing research program to develop measures for individual and unit performance and to identify the training, leadership, and doctrinal determinants of effective combat performance. Part of the program was to maximize the research benefits for other ARI projects. Consequently, the research plan outlined a study which utilized the information gathered from a leadership focused rotation at the NTC to collect data on the effects of sleep loss.

The proposed research plan included eight phases as follows:

1. Literature review (previously discussed)
2. Examination of NTC data
3. Identification of research objectives
4. Development of a data collection and analysis strategy
5. Development of data collection instruments
6. Data collection
7. Data analysis
8. Preparation of the report

The second step in the research plan was to assess the potential for using existing NTC data to examine the effects of sleep loss on selected individual and unit performance measures. There are eight major sources of NTC data provided by Observer-Controllers (OCs) and the instrumentation system in use there. These are: history tapes; NTC tactical database; live fire data; communication tapes; Observer-Controller (OC) notes; video tapes of after-action reports (AARs); unit take home packages; and NTC focused rotation data. The last source was of greatest interest because data can be collected for specific purposes during these rotations.

The possibility of examining existing NTC data was evaluated for its appropriateness to the current effort. It was determined that existing data would not be suitable for the current study due to the lack of data on sleep patterns or other measures of fatigue. The existing data does however, support assessments of other measures of unit effectiveness such as movement rates, navigation accuracy, synchronization indices, engagement ranges, weapon availability, and gunnery.

Another source of data was determined to have potential for this effort. The Walter Reed Army Institute of Research (WRAIR) previously conducted an NTC focused rotation using wrist worn activity monitors to collect sleep/rest data. Although this data focused on battalion staff officers' sleep patterns, the technique offered a relatively objective method for collecting sleep loss data.

The Leadership and Management Technical Area at ARI scheduled an NTC focused rotation in February 1988 to examine platoon level leadership. Through coordination with LMTA and WRAIR it was agreed to "piggyback" the use of the wrist activity monitors (and some additional sleep items) on this platoon level leadership data collection.

The focused rotation was viewed primarily as a pilot study to examine the feasibility of conducting more extensive data collection during future rotations. The research objectives for the focused rotation were:

- Collecting observational data to verify that the periods of inactivity recorded by the activity monitors corresponded to periods of sleep obtained by the research subjects.

- Collecting data indicating the extent to which leaders attempt to enforce some type of sleep/rest plan during the continuous operations environment at the NTC.

- Collecting data to examine the extent to which SMEs are able to observe behaviors indicating how the lack of sleep impacts on the performance of critical leadership tasks such as communicating to subordinates.

- Examining the extent to which self-report estimates of the average amount of sleep obtained during the NTC rotation made by members of the units wearing wrist activity monitors correspond to SME observations and wrist activity monitor data.

- Examining the feasibility of linking the wrist activity monitor data and/or observational data on performance of critical leadership tasks to measures of unit performance normally collected through the automated data collection process or Observer-Controller (OC) records.

The fourth step in the research plan was the development of a strategy for collecting and analyzing data from the focused rotation. The strategy included four sources of data to collect. The first was self-report data from participating soldiers. This took three forms: 1) Pre-rotational data collected through surveys administered to the unit several weeks before they went to the NTC; 2) Data directly from subjects wearing the wrist monitors at the time the monitors were returned at the end of the rotation; and 3) Information collected during post-rotation interviews conducted at the unit's home station. The second data collection source was the automated data provided by the wrist activity monitor during the NTC rotation. The third data source was the observational data collected by the SMEs and the OCs during the focused rotation. The final source of data was the leader and unit performance data normally contained in the automated records and take-home packages prepared by the NTC OCs.

The data analysis planned for this effort included several types of analyses. Descriptive statistics examining the average amounts of sleep obtained by individuals in different organizational positions would be calculated. Analyses would also be conducted to compare wrist activity data to observations and self-report data on sleep obtained by research subjects. Also, the data would be analyzed to provide an indication of the extent to which units actually enact any type of sleep/rest plans during the rotation.

The fifth phase of the research plan was the development of the data collection instruments. These consisted of a pre-rotation and post- rotation questionnaire, OC and SME ratings, and the raw data from the wrist monitors worn by participants. The purpose of the pre-rotation questionnaire was to obtain a self-report measure on the average amount of sleep normally obtained by unit members and to determine the steps they have taken at their home station to prepare for the continuous operation environment at the NTC. The post-rotation questionnaire was developed to be similar in format and content to the pre-rotation questionnaire for comparative purposes. Observation guides were developed for the OCs and the SMEs which focus on the collection of data on platoon sergeants, platoon leaders, company commanders, and other leaders wearing wrist activity monitors. The observation guides were developed with the intention of enabling the observer to record distinct and observable actions performed by the leaders. The information required included the time an individual went to sleep or recording the presence or absence of specific behaviors or events.

The sixth phase of the research plan was to collect the data. The Leadership and Management Technical Area of ARI and the Walter Reed Army Institute for Research (WRAIR) had proponency for the data collection effort. The information gathered from the data collection was sent to HTI for analysis purposes.

The seventh stage of the research plan was to conduct the analysis on the data to determine trends and relationships. The goal of the data analyses is the establishment of direct or indirect links of measures of sleep/rest to measures of the performance of critical functions.

The final phase of the plan was the preparation of this report. It documents the research process and the findings from the focused rotation as well as information gathered from previous rotations using the wrist monitors.

Research Methodology

As the project focus evolved, there was a determination to tap and correlate data from four possible sources available in the NTC environment during this rotation. As noted earlier, the rotation was a Leadership focused rotation sponsored by the Center for Army Leadership (CAL) and the Center for Army Lessons Learned (CALL), with research support from ARI's

Leadership and Management Technical Area (LMTA) and WRAIR. The four data sources available as a result of their efforts included:

- Self-Report/Self-Evaluation data from participating soldiers;
- Subjective unit performance data from Observer-Controllers and Subject Matter Experts; and
- Sleep/Activity levels measured with wrist monitors;
- Objective Performance Data from NTC Automated Tracking/scoring equipment.

Data collection items, procedures and instruments for the first and second sources were developed by LMTA. Their purpose in developing and administering the instruments was to assess the relationship of platoon leadership and combat performance, and as a step in the development and validation of measurable leadership tasks and performance standards.

The participating soldiers, from Mechanized Infantry and Armor units, were administered the pre-rotation and post rotation questionnaires by LMTA staff. Soldiers were asked to provide ratings on leadership, attitudes, commitment, morale, training adequacy and training quality. The pre-rotation questionnaires also included requests for demographic data and information on each individual's military and unit history and responsibilities. Although the question areas were comparable across questionnaires, and many questions were the same, five separate pre-rotation and post-rotation forms were developed with individual items specific to the duties and positions of:

1. Unit Soldiers E1 - E4
2. Squad Leaders/Tank Commanders
3. Mech infantry Platoon Leaders/Platoon Sergeants
4. Armor Platoon Leaders/Platoon Sergeants
5. Company Commanders/1ST. Sergeants

The LMTA also developed two Observer-Controller (OC) observation guides. One type included rating scales on 3 separate 3X5 cards and was completed by the OCs for each mission (both force-on-force and live fire). The second type was in booklet format and was completed at the end of the rotation by the OCs for the unit they observed. The three cards and the after-rotation ratings included OC evaluations of Platoon Leader and Platoon Sergeant performance as well as the effect of leadership and sleep loss on overall mission accomplishment. Specifically, the first card requested OC ratings on Platoon Leader and Platoon Sergeant performance on:

- Planning
- Communication
- Supervision
- InitiativeoSoldier/Team Development
- Overall Effectiveness as a Leader

The second card requested their subjective ratings of the following performance areas:

- Platoon Leader Consulted with the Platoon Sergeant in planning, key decisions;

- Platoon Leader Informed the Platoon Sergeant About Changes Affecting Tactics/Supply/Mission;

- The Platoon Sergeant Supported the Platoon Leader;

- The Platoon Sergeant took Care of Logistics/Supply; and

- The Platoon Leader/Platoon Sergeant had Clearly Defined Roles with Effective Delegation/Sharing.

The third card provided scales for the rating of the "Effectiveness Level" of the Platoon as a unit in accomplishing its mission and the importance of the Platoon-Level Leadership and Leader sleep loss to Mission Accomplishment.

HTI provided input to LMTA on the content of questions for the OCs and for Subject Matter Experts (SME) on sleep patterns, sleep loss and performance/sleep loss relationships. It was felt that this data along with the leadership data being collected by and for the LMTA provided a rich source of information for the examination of a human variable (fatigue) on performance.

As noted above, the ARI LMTA also developed Subject Matter Expert Observation guides that were completed by SMEs for each mission. The SMEs were ARI headquarters staff who accompanied NTC OCs and tracked individual units throughout the rotation. Because of the number of items and the conditions of the field, many of the SMEs did not carry the evaluation booklets with them to the missions. Inconsistencies in the completeness and content of the responses prevents the use of the SME booklets as quantifiable data sources. They do provide, however, process information relevant to understanding individual leadership and performance related events and decisions, and provide institutional knowledge relevant to the interpretation of other data available from this rotation.

The remaining two data sources, the automated performance measure and wrist monitor data, unlike the previously discussed data measures, were objective in nature and provided quantified measures of performance and sleep. As such, they provided a means of validating the OC, SME and soldier subjective ratings of the effects of sleep loss on performance. Also, because they were objective measures, they were hoped to be invaluable in demonstrating an impact of a human variable on performance as well as demonstrating the viability of NTC as a research data source for future efforts in this area. The ARI field unit at Monterey collects and stores the unit performance data (including information on hits/misses, movement, time to kill, rounds to kill, survival ratios, etc.).

The sleep/activity data were collected and scored by The Walter Reed Army Institute for Research. They have developed unobtrusive wrist monitors that can be worn by soldiers throughout a full rotation and that accurately indicate sleep and activity schedules and levels. They have used the wrist monitors during prior rotations and agreed to provide ARI and its contractors with data wrist monitor data collected and scored on unit level soldiers for this rotation. It is important to note that WRAIR has a limited number of wrist monitors and randomly assigned their total of 68 monitors to commanders, platoon leaders and platoon sergeants across both the Mechanized and Armor Battalions and across companies within the two battalions. They also selected two tank crews to instrument. All unit/platoon leaders and sergeants were not, therefore, instrumented. WRAIR also collected self-report data from all instrumented soldiers on sleep patterns, attitudes towards the wrist monitor intrusiveness, comfort, etc., and estimated NTC sleep levels. These data were also made available to ARI and contractors on this project.

The ARI L&M Technical Area have completed some analyses on the data collected, examining the relationship of leadership, experience, cohesion, etc. and OC/SME generated performance ratings. WRAIR is examining sleep cycles and patterns by rank and Vector is examining the objective performance data of NTC. They are assessing the viability of using these data for research into the impact of human variables on performance as well as examining the correlation of objective performance data to OC/SME generated performance scores. HTI accepted the responsibility of examining the OC/SME data and the WRAIR sleep data to assess if there is a tie between sleep patterns/levels and the subjectively rated unit performance. HTI also accepted the responsibility of examining the pre- and post-rotation questionnaires and resulting data to assess if possible relationships between sleep patterns and experience, longevity in the unit, unit leadership ratings, etc.

Results

Following the collection of data, the LMTA group conducted an initial analysis of the Observer-Controller data in comparison to information collected through the administration of the pre-rotation questionnaires. As a result of this initial analysis, they identified six units that could be considered high performing units, or those obtaining Observer-Controller after-rotation ratings of "at or above standard" for overall mission performance and overall Platoon leader and Platoon Sergeant performance. They also identified five low performing units, again, based on Observer-Controller after-rotation ratings of overall mission performance and overall platoon leader and platoon sergeant ratings.

HTI examined the Observer-Controller performance data on a mission by mission basis and generated a similar list of high and low performing units. Performance scores were calculated as an average of mission-by-mission Observer-Controller ratings of platoon leader and platoon sergeant leadership performance. The HTI list resulted in only three low performing groups and two high performing groups, all of which were included in the LMTA units. HTI conducted an assessment of the mission-by-mission scores of those LMTA designated high and low performing units to examine the differences in high and low designations. As can be seen from figure D-1, there is a pattern of somewhat improved performance over missions for the LMTA designated high performing units and inconsistent to degrading performance on the part of the low performing units. The one mission on February 7 that indicates a significant improvement for the low groups is misleading in that scores for only one unit comprise that data point. (Statistical analyses and comparisons were not conducted on the differences

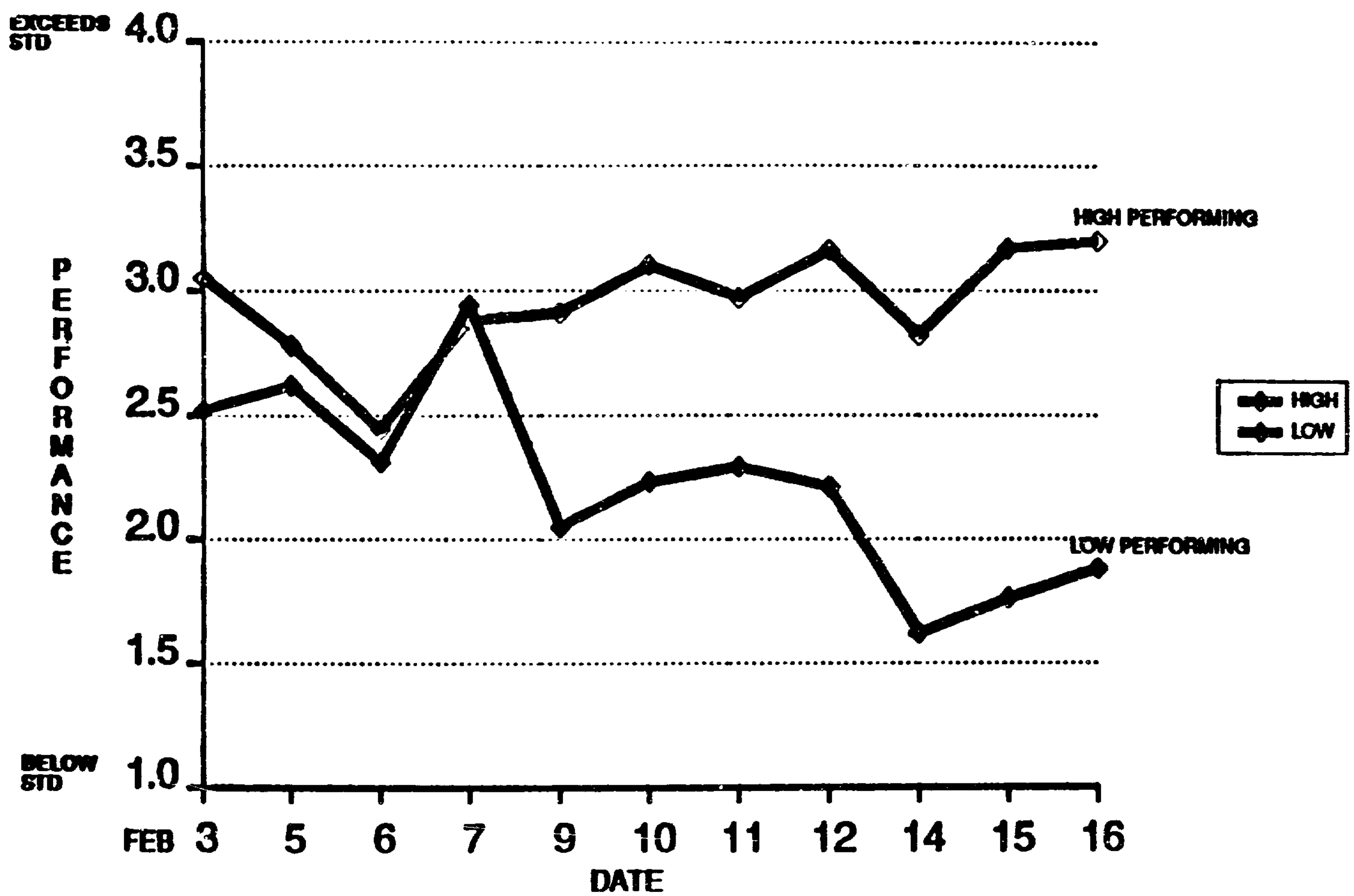
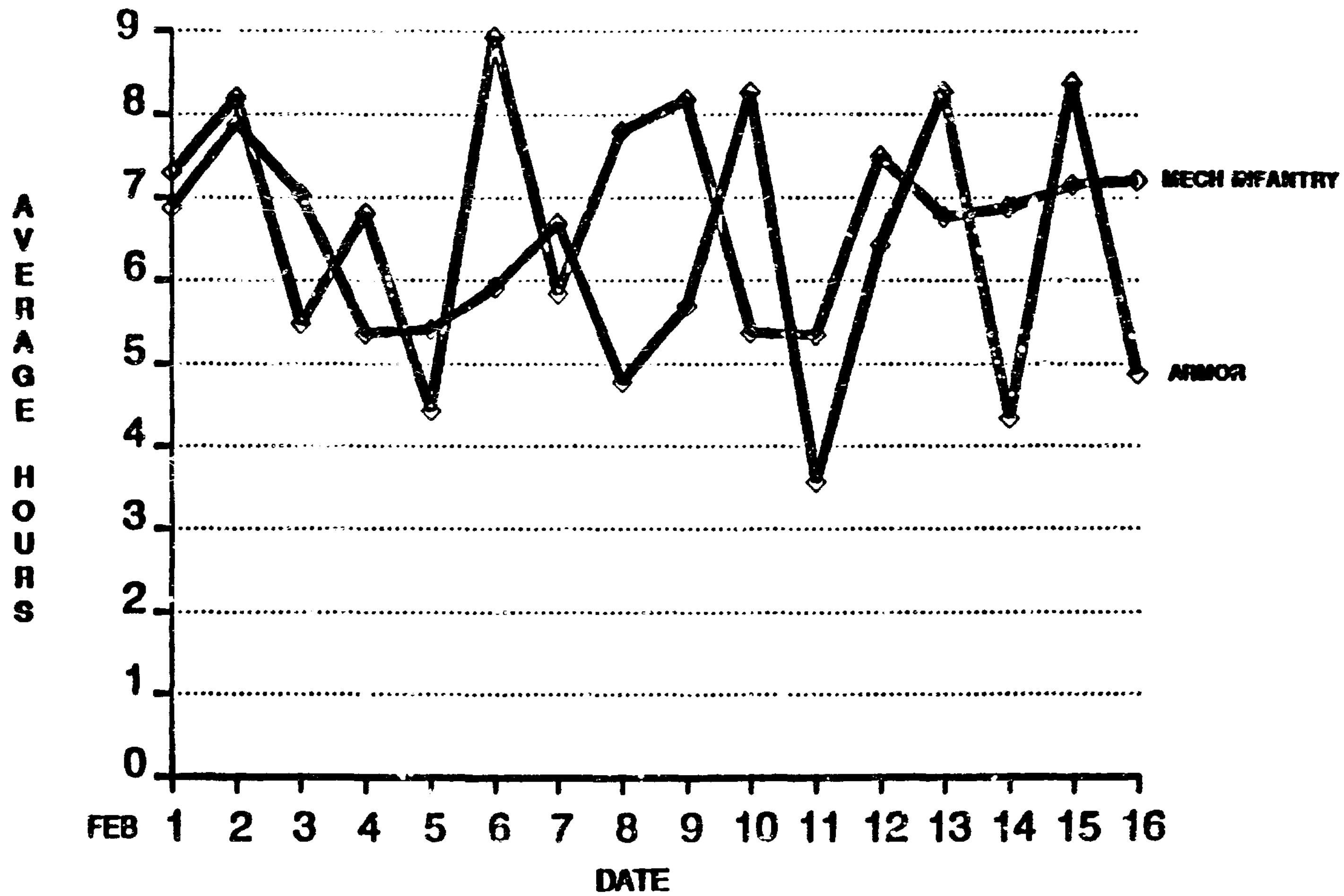


FIGURE D-1. AVERAGE SCORES FOR HIGH AND LOW GROUPS (DURING ROTATION DATA) between the two groups because of instances such as this where limited data exist.) Data gaps such as these resulted in a flattening of average performance scores for several of the units. This resulted in the units not being designated as either high or low performing on the basis of mission-by-mission scores. As can be seen from the figure though, the lower performing units were lower in performance upon entry into the rotation. It seemed viable, therefore, to maintain some consistency across analyses being conducted on these data and to use the LMTA designation of high and low performing unit for further data comparisons with sleep data, self-report data, SME data, etc.

In examining the sleep data provided by WRAIR, HTI discovered that only one of the high performing units had received wrist monitors and none of the low performing units had received monitors. The wrist monitors were randomly distributed and assignment of monitors in a subject pool with relatively few high and low performing groups resulted in most monitors being assigned to average performing groups. Therefore, above or below standard performance by unit could not be directly tied to objectively measured sleep deprivation or accrual. There were some patterns that were examined, however, in an effort to determine the viability of future research in this area and to provide information that could contribute to research design considerations.

Sleep per day averages for those monitored does not on first review seem to indicate a sleep deprivation, with individual averages over the rotation falling between 5 and 8 hours of sleep per night. (Please note, sleep data referred to in this report include only platoon leader and platoon sergeant measures. WRAIR assessment will include command group sleep data as well as that examined for this report.) These figures might be a bit misleading, however, as much of the sleep was acquired in sporadic sessions, with frequent interruptions or several small naps over a 24-hour time period. On a day by day basis, individuals also experienced 24-hour periods with less than 4 hours of sleep. Their overall average was higher because almost all instances of low sleep were followed relatively quickly by a 24-hour period with up to 8 hours of sleep or more. The longest time period of low sleep was shown by the Armor Task force early in the rotation, where they experienced 3 consecutive days with less than 6 hours of sleep per day but at least 5 hours per day. (Further and more detailed interpretation of the sleep data will be undertaken by the WRAIR staff, as they examine sleep patterns and amounts by area of responsibility, rank, mission, etc.)

Because there were two task forces (an Armor Task Force and a Mechanized Infantry Task Force) with separate mission schedules, average hours of sleep per day were charted by Task Force to determine if sleep patterns were related to mission schedule. Figure D-2 illustrates the sleep per day patterns of the two Task Forces. As can be seen, sleep patterns clearly vary for the two Task Forces. Average sleep by Task Force per day does not, however, seem to indicate critical sleep shortages or low sleep days without a day for some recovery sleep following close behind. This task force pattern is reflective of individual sleep patterns, where recovery sleep was generally obtained within 24 hours of a low sleep period.



* EACH 24 HOUR PERIOD WAS CLOCKED FROM NOON TO NOON

FIGURE D-2. AVERAGE HOURS OF SLEEP PER 24 HOURS*

As noted, sleep patterns were charted by task force to allow for an assessment of a possible relationship to mission schedule. As a further step in this analysis, average performance ratings were calculated for the two Task Forces by date. These performance averages are presented in figure D-3. Table 1 lists the mission types and start times for further examination of scenario flow and comparison to sleep patterns. As can be seen from the sleep and performance figures and the mission schedules, the sleep patterns do appear to correlate to mission schedules but performance variation is small and does not apparently vary with sleep patterns. The one exception is the minor dip in performance for the Armor Task Force following the 3 days of averaging less that 6 hours of sleep per day. This was, however, also their first force-on-force (FOF) mission following three live fire missions. The ratings on performance for this mission are therefore not easily attributable to sleep loss/fatigue, as they could also be affected by the change in mission type as well as change in the Observer-Controllers providing ratings.

Table 1

Mission Schedule and Mission Type for Task Force I, Mechanized Infantry Task Force

DATE	MISSION START TIME	MISSION TYPE*
Feb 3	0800	Hasty Attack FOF
Feb.5	0400	Defense In Sector FOF
Feb.7	0600	Deliberate Attack FOF
Feb.10	0800	Joint Air Att/Day Defense LF
Feb.10	2100	Night Defense LF
Feb.11	0900	Offense LF
Feb.14	0545	Bde Defense In Sector FOF
Feb.15	0600	Bde Hasty Attack FOF
Feb.16	0615	Bde Delay FOF

* FOF - Force on Force
LF - Live Fire

Mission Schedule and Mission Type for Task Force 2 Armor Task Force

DATE	MISSION START TIME	MISSION TYPE
Feb.5	0800	Joint Air Att/Day Defense LF
Feb.5	2100	Night Defense LF
Feb.6	0900	Offense LF
Feb.9	0530	Defense in Sector FOF
Feb.11	0300	Night Attack FOF
Feb.12	0600	Mvmt to Contact/Engagement FOF
Feb.14	0545	Bde Defense in Sector FOF
Feb.15	0600	Bde Hasty Attack FOF
Feb.16	0615	Bde Delay FOF

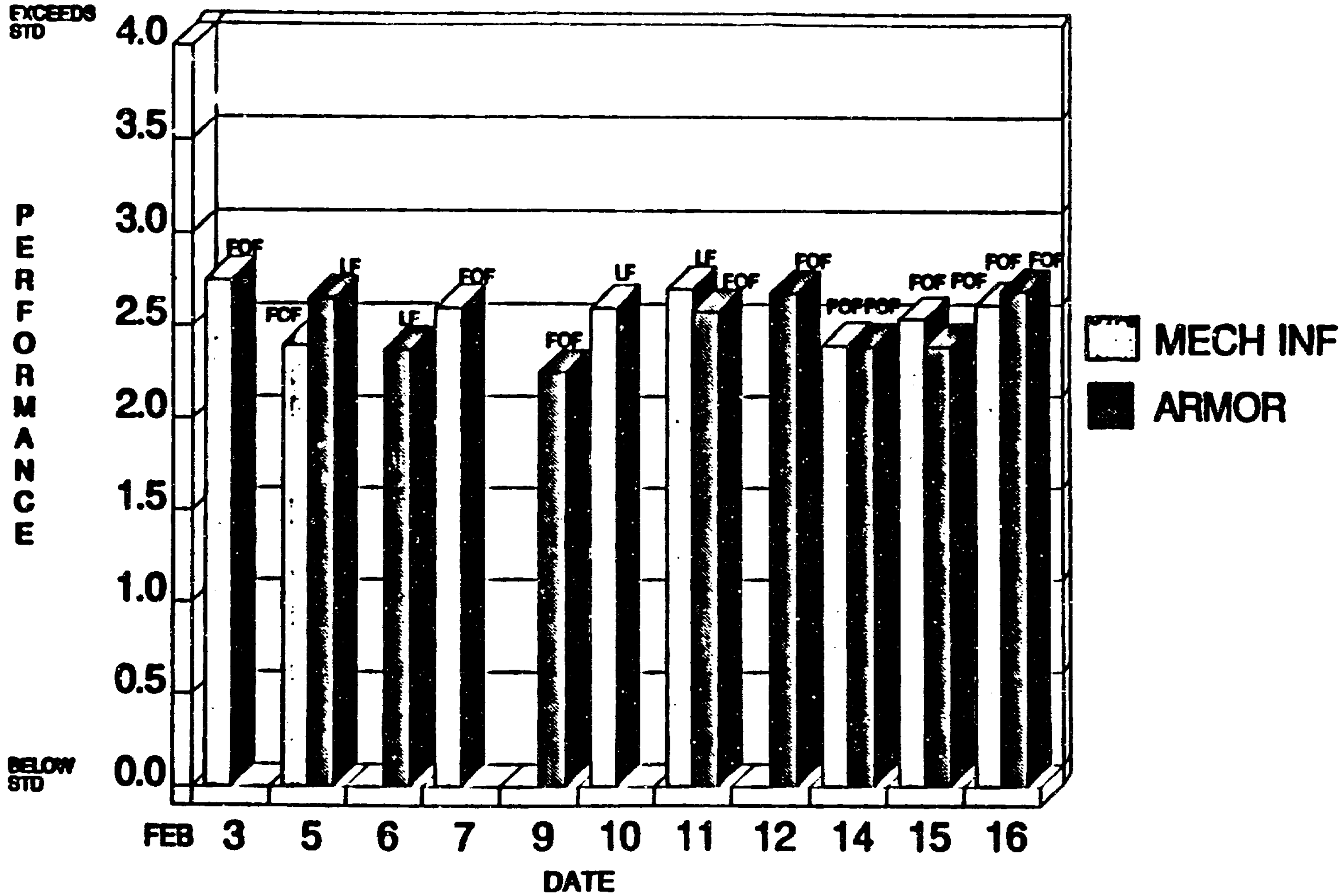


FIGURE D-3. AVERAGE PERFORMANCE BY TASK FORCE (DURING ROTATION DATA)

Because the performance scores reported in figure D-3 included all task force member scores, and wrist monitor data was from a random sample, average performance scores were calculated for only those members of each task force wearing a wrist monitor. It was felt that by restricting the examination of performance scores to those with sleep data, a more valid examination of a performance to sleep relationship could be accomplished. The performance scores for wrist monitored individuals in Task Forces one and two are presented in figure D-4. As can be seen, the monitored group performance patterns are reflective of the total group performance pattern (even to the dip in performance on the Armor Task Force's first FOF mission) and again not indicative of correlation/relationship to sleep patterns.

As noted earlier, objective performance measures (i.e., automated system performance measures) may provide further data that will be sensitive and related to recorded sleep patterns. To insure this possibility is examined, HTI has provided the code numbers of the units who were monitored and the code numbers of the high and low performing units to Vector Research, for consideration in their examination of the NTC range data.

Additional subjective data were, however, also available from the Observer-Controllers, providing ratings of mission-by-mission evaluations of unit performance and a subjective rating of the impact of sleep on overall unit performance (versus the platoon leader and platoon sergeant leadership ratings used for the comparisons in the tables above). The Task Force by mission averages for the ratings of mission-by-mission unit performance and the impact of sleep on performance are reported in figures D-5 and D-6. Overall unit performance was reported as fairly consistent across missions, and reflects the Observer-Controller leadership performance ratings (see figure D-3). The impact of sleep loss on mission accomplishment is also not apparently significantly variable across mission types or task force type, with the exception of the ratings provided on February 14, the first brigade mission in which both Task Forces participated. For that one mission, Observer-Controllers felt the performance of the Armor Task Force was far more affected by sleep loss than that of the Mechanized Infantry Task Force. This is interesting in that their performance ratings do not widely differ for that mission. However, the monitored Task Force 2 members did have slightly less sleep than their Task Force 1 counterparts (See figure D-2). Observer-Controllers might, therefore, have been responding to sleep deprivation related behaviors. They did not, however, feel or report a degradation of unit or leadership performance for this mission.

When sorted for the High and Low performing units, differences were found in the sleep impact ratings. The performance of the highly rated units was reported as being more impacted by sleep deprivation than the low performing units. (Again, statistical tests were not performed because of the small number of subjects and the short range of possible values, but the trend is consistent and possibly worthy of further examination.)

As an added point of examination, HTI also charted pre-mission sleep accumulation. Noting that task forces have fairly distinct patterns of sleep, it was felt that examination of the accrued sleep over 24, 48 and 72 hours prior to each mission might be important in assessing possible performance impact. Table 2 lists the pre-mission sleep patterns for each

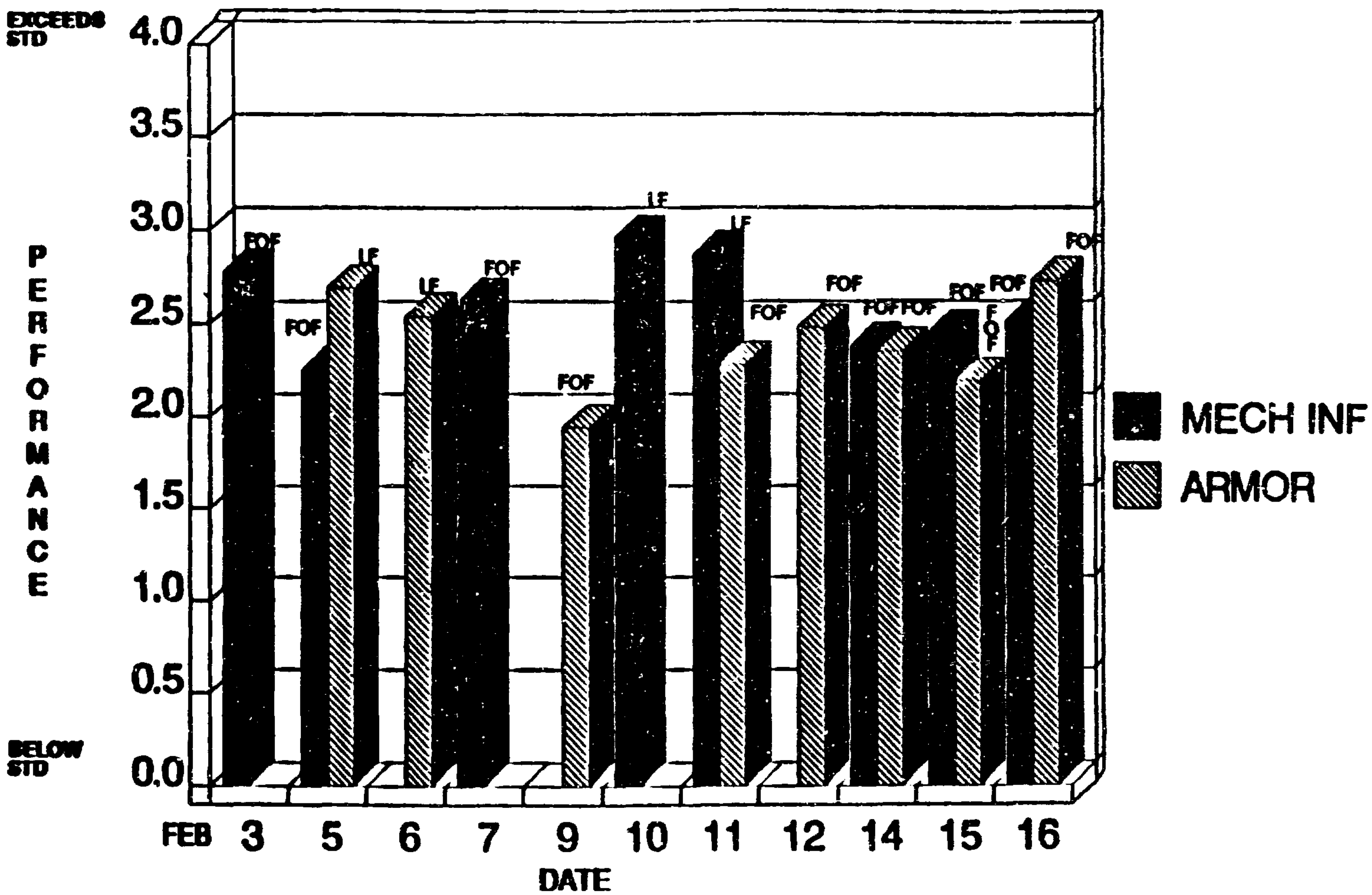


FIGURE D-4. AVERAGE PERFORMANCE BY TASK FORCE (UNITS WITH WRIST MONITORS)

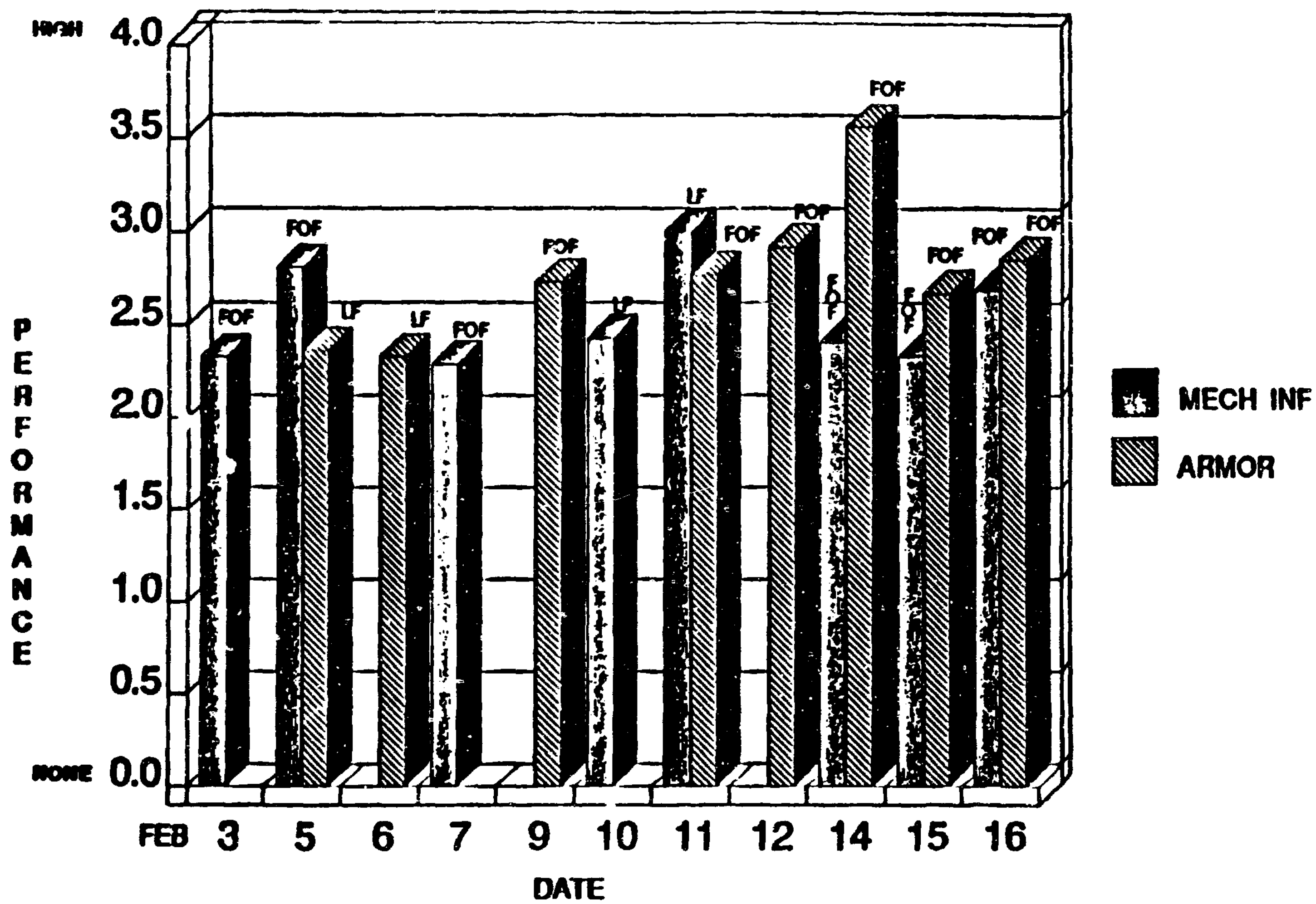


FIGURE D-5. OVERALL MISSION EFFECTIVENESS RATINGS (DURING ROTATION DATA)

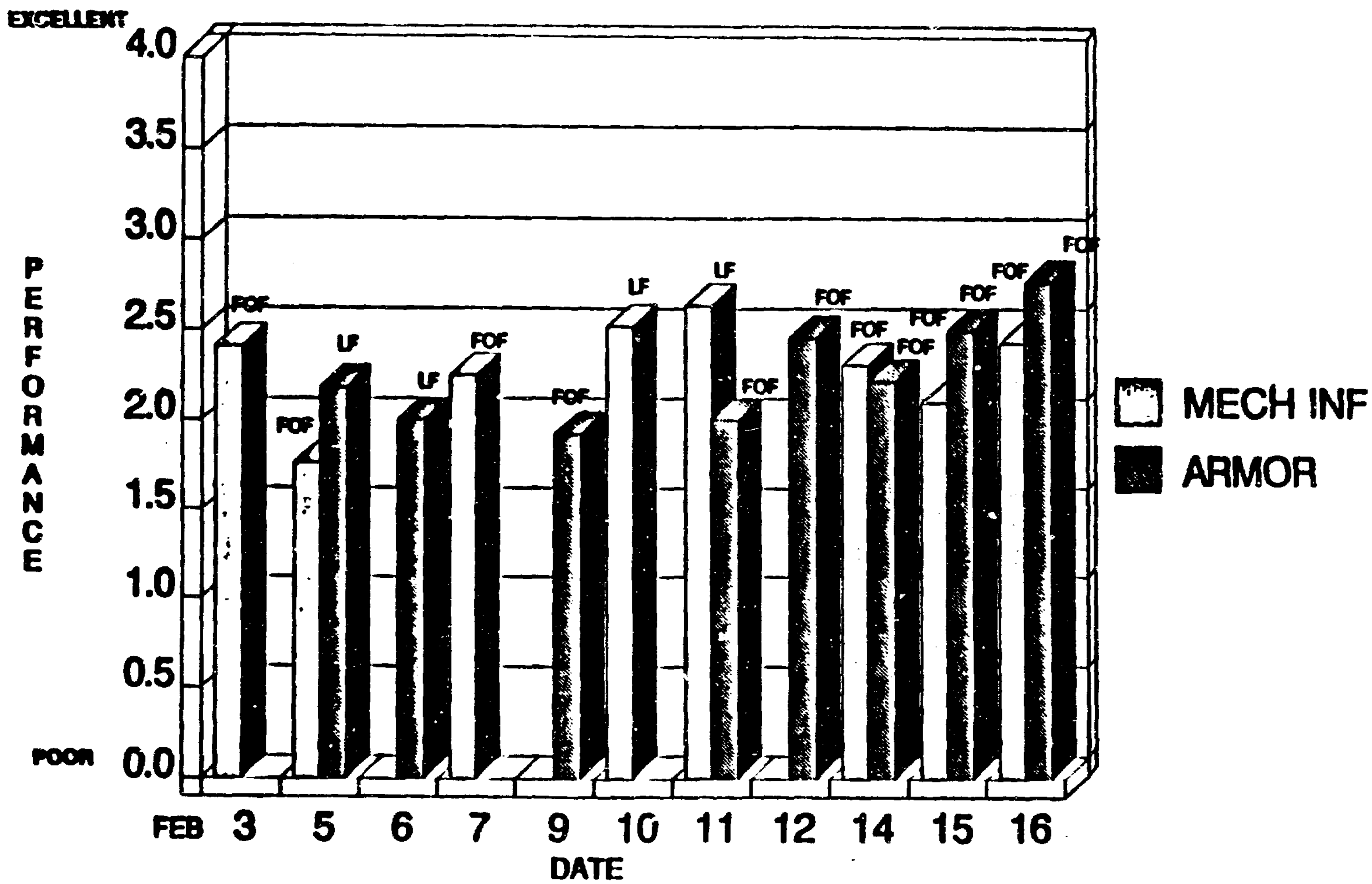


FIGURE D-6. RATINGS OF IMPACT OF SLEEP LOSS ON MISSION (DURING ROTATION DATA) task force. As can be seen, pre-mission accrual is fairly constant over any 24 to 72 hour cycle, except for the slightly lower 3.57 hours of sleep the Armor Task Force obtained on the February 10-11, 24-hour period. Even with this one day of sleep loss, the patterns still seem to indicate that although there may be sleep loss for any one 24-hour period, recovery or accumulation of sleep over 48 hours to 72 hours may have ameliorated the effects and prevented the occurrence of noticeable sleep-deprivation. Performance impact would be expected to be negligible for noncognitively-based tasks with this type of sleep pattern.

Table 2

Pre-Mission Sleep Accumulation
Mechanized Infantry - Task Force 1

Mission			Accumulated Sleep Pre-Mission		
Date	Time	#	24hrs.	48hrs.	72hrs.
Feb 3	0800	1	5.48	13.68	20.98
Feb 5	0400	2	4.45	11.25	16.73
Feb 7	0600	3	5.85	14.78	19.23
Feb 10	0800	7	5.38	13.55	21.35
Feb 10	2100	8			
Feb 11	0900	9	5.35	10.73	18.9
Feb 14	0545	4	6.68	13.45	20.93
Feb 15	0600	5	7.15	13.83	20.60
Feb 16	0615	6	7.20	14.35	21.03
Armor - Task Force 2					
Feb 5	0800	13	5.42	10.79	17.82
Feb 5	2100	14			
Feb 6	0900	15	5.92	11.34	16.71
Feb 9	0530	10	5.70	10.48	17.16
Feb 11	0300	11	3.57	11.82	17.52
Feb 12	0600	12	6.43	10.00	18.25
Feb 14	0545	4	4.35	12.62	19.05
Feb 15	0600	5	8.38	12.73	21.00
Feb 16	0615	6	4.88	13.26	17.61

In view of the sleep pattern and sleep accumulation values, it is interesting to note the consistent reporting of sleep deprivation. Self-perceptions of sleep deprivation and its impact on performance were systematically collected and available for analysis as was subjective ratings of Observer-Controllers and SMEs. There were clear differences between the perceived lack/loss of sleep and the measured amounts of sleep. For example, WRAIR staff asked the monitored individuals to assess how much sleep they thought they averaged per day for the rotation. These ratings have been compared to the actual sleep per day averages and are reported in Tables 3 and 4, and figures D-7 and D-8. As can be seen, regardless of battalion type or area of responsibility, rotation participants perceived themselves as obtaining much less sleep than they actually managed to get.

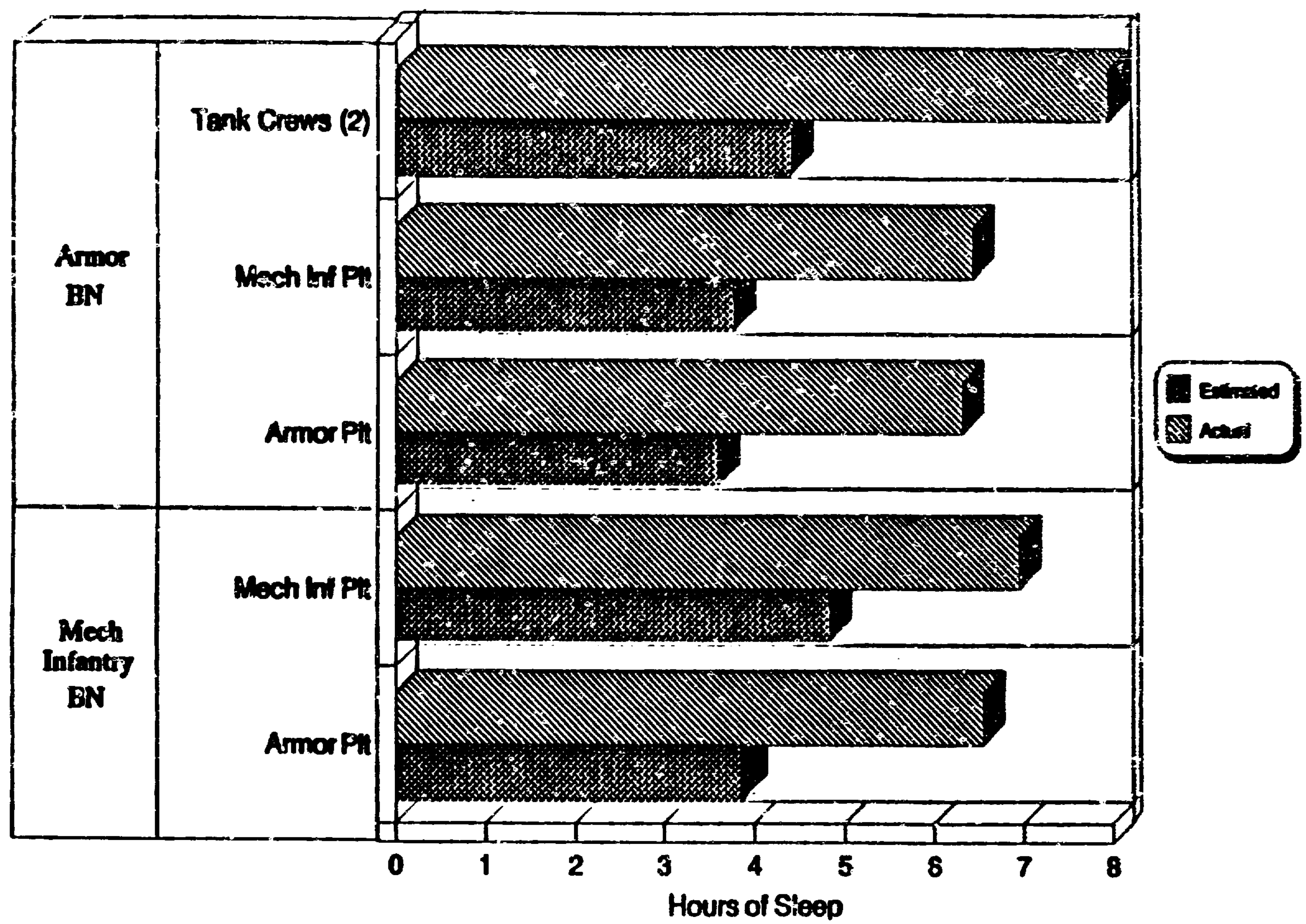


FIGURE D-7. ESTIMATED VERSUS ACTUAL AMOUNT OF SLEEP BY PLATOON

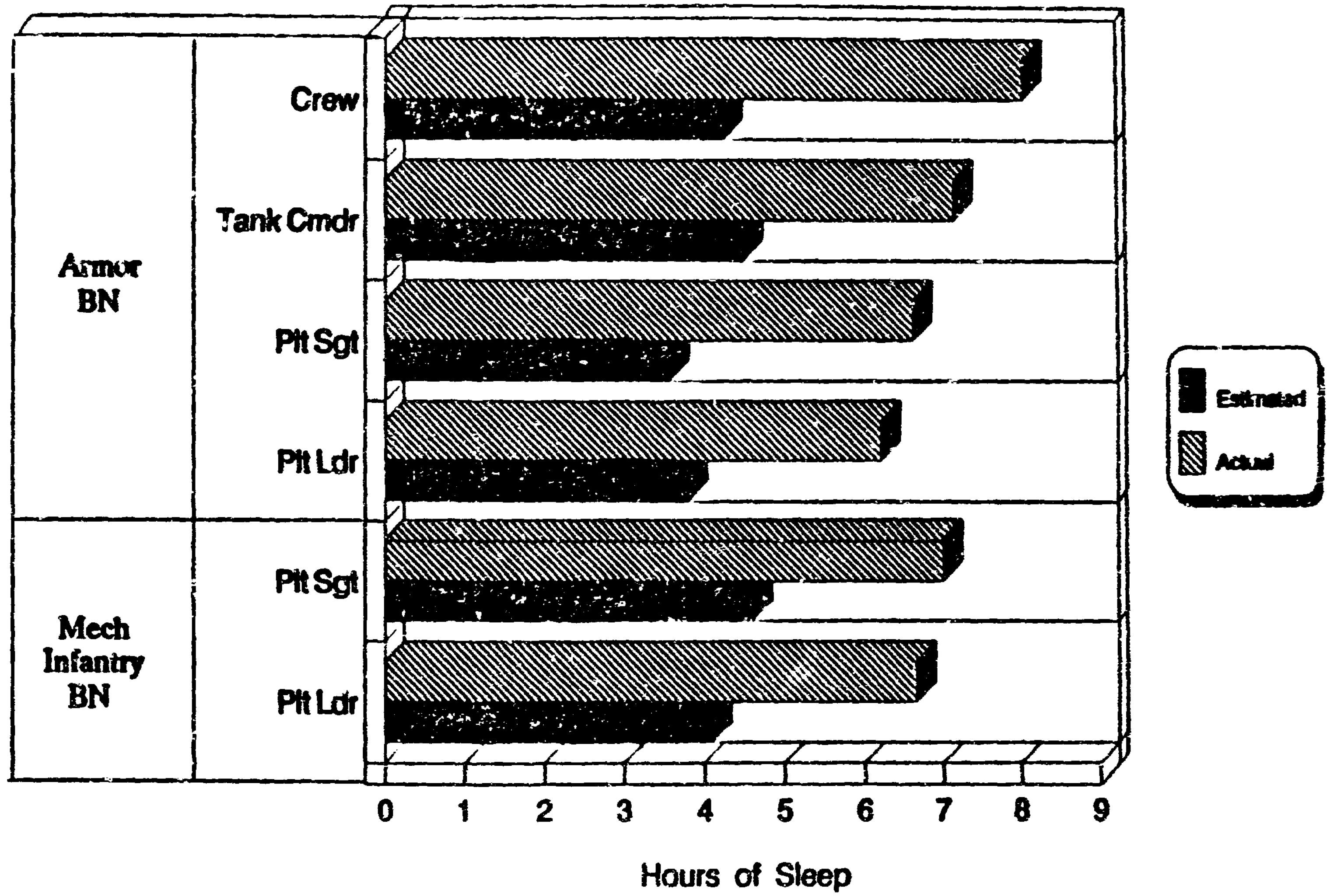


FIGURE D-8. ESTIMATED VERSUS ACTUAL AMOUNT OF SLEEP BY ASSIGNMENT

The differences for all comparisons are significant, indicating an inability of these subjects to accurately judge sleep loss and accrual in this environment.

What was not clearly answered by these analyses, however, is the impact of sleep patterns or sleep loss on the performance of these subjects in this environment. As this issue is critical to the ability to incorporate human variables impact in combat models, further work is discussed and recommended in the following sections.

Table 3

Summary Statistics for Estimated and Actual Hours of Sleep by Platoon

Group	n	Mean Difference (Hrs:Min)	Standard Deviation (Hrs:Min)	t-Test
Mech Infantry BN				
Armor Plt	5	2:39	1:16	4.73*
Mech Inf Plt	6	2:02	1:27	3.59*
Armor BN				
Armor Plt	5	2:44	1:48	3.41*
Mech Inf Plt	7	2:40	1:06	6.33**
Tank Crews (2)	6	3:19	0:55	9.32**

* $p < .05$ ** $p < .01$

Table 4

Summary Statistics for Estimated and Actual Hours of Sleep by Assignment

Group	n	Mean Difference (Hrs:Min)	Standard Deviation (Hrs:Min)	t-test
Mech Infantry BN				
Platoon Leader	5	2:34	1:34	3.66*
Platoon Sergeant	5	2:25	1:14	4.38*
Armor BN				
Platoon Leader	5	2:25	1:06	4.94**
Platoon Sergeant	6	3:03	1:40	4.49**
Tank Commander	3	2:40	1:07	4.09
Crew	4	3:48	0:45	10.00**

* $p < .05$ ** $p < .01$

Conclusions

The focus of this effort was to assess the impact of the human variable of sleep deprivation on performance, for the purpose of assessing the potential of incorporating this impact in combat modeling. This product would then provide a framework for the measurement and inclusion of other human variables into performance predictive models. Unfortunately, data obtained from this project were not definitive enough to be able to assign weighted values fcr use in a combat modeling effort.

In the data reviewed by HTI, acute sleep deprivation was not evidenced. The wrist monitor data for platoon leaders and platoon sergeants did not evidence any extended periods with sleep loss at a level that would be expected to impact on performance. Although performance measures were not available to support it, the presenting disrupted sleep patterns and the measured lowered average of sleep per night were such that they would likely impact on cognitive performance and command and control decisions, but would probably not impact on physically demanding tasks, overlearned tasks or normal operating procedures. As research has shown, the effect on combat tasks for weapons crews are minor when some sleep is possible (Headley, et.al., 1988; Drucker, et. al., 1969; Ainsworth & Bishop, 1971). The disrupted and lowered nightly sleep average might, however, contribute to a sense of fatigue, (as clearly reported by the subjects monitored). The impact on performance, however, would probably not be evident in gross measures, on broad subjective ratings or without measurement of fairly discrete performance parameters throughout the exercise.

As cognitive performance parameters are more sensitive to sleep loss and sleep cycle disruption, an impact on more finitely delineated cognitively related tasks would have been more likely than the broader performance measures taken during this rotation (WRAIR, 1987). In addition, broad task measures would potentially provide sleep deprivation sensitivity if acute and continued sleep loss were existent, and it was felt NTC would create this situation, broad measures were anticipated as being relevant and useful. At least for this rotation, however, that performance environment was not evidenced. Performance ratings on select task requirements of command and control personnel might, therefore, have shown more sensitivity to the impact of the sleep patterns reported here. Their decision making responsibilities can be assumed to be more cognitively demanding and sensitive to the patterns reflected in the current measures, than the performance tasks assessed for platoon le ders and platoon sergeants.

One interesting effect that was clearly demonstrated in the data, however, was the self-perception of sleep loss or sleep deprivation. Although not a focus of this research, the impact on motivation, morale, etc., and ultimately performance of soldiers who perceive their condition as degraded could be critical in a combat environment. Research has demonstrated a clear relationship between motivation and performance, even with sleep deprivation (WRAIR, 1987; Solick & Michel, 1983). Although difficult to incorporate in a field-based study, it might be valuable to assess the impact of accurate feedback on performance, with an eye towards determining if performance enhancement might be possible.

Another finding that is relevant to possible future research efforts is the evidence that the Observer-Controllers rated mission accomplishment of the high performing units as more susceptible to sleep loss than mission performance for the low rated units. Since sleep patterns are not available for either group, it is not possible to assess if differing sleep patterns and, therefore, related behaviors contributed to this rating effect or whether OC biases impacted their rating behavior. Current data could suggest that the OCs felt that consistently low performing units were inadequate to performing the tasks and external factors were not critical to the outcome, while higher performing units were perceived as performing with more precision and, therefore, more susceptible to the impact of sleep deprivation. It could, however, also suggest that the tasks monitored for these units were not discrete or operationally defined enough for the questions asked in this effort and, therefore, more affected by subjective judgment and biases.

In summary, low sleep periods for those monitored were either not at a diminished level that would critically affect the performances measured or the measurement procedures were not sensitive enough to reflect the impact of the sleep pattern variations or sleep levels of this rotation. Another consideration, again unsupportable with the current data, is that the ameliorating sleep seemingly regularly accrued by the monitored soldiers in this rotation might be adequate to prevent critical performance degradation in this type of scenario/environment. Unfortunately, again, the measures used in this project were not sensitive enough to be able to assess this potential or to determine the operating variables.

Recommendations

In an effort to prevent duplication of effort and lengthy planning periods and delays in access to an NTC rotation, this project attempted to utilize planned leadership performance data collection efforts. Although the measures were valid for their intended use, they were apparently not discrete or sensitive enough to reflect an impact of soldier sleep patterns. The data collection items and procedures at least need in-depth exploration. As an adjunct to this, more sensitive measures must be defined in order to assess more clearly if sleep deprivation (as present in NTC environment) does or does not impact critical performance parameters at the unit level. This appears essential regardless of the human variable being examined. Defined behaviors that can be checked as occurring or not occurring would provide for more definitive data for analysis of the impact of human variables, especially at the unit level, where clear performance, behavioral requirements are present and assessable. This reduces the inconsistency of subjective rating criteria, focuses observations onto finite behaviors and provides clear data points for measurement.

As evidenced by the extensive amount of data collected, however, both subjective and objective, data collection is clearly possible at NTC without being obtrusive or intrusive to the training focus or the combat realism desired. The implications of the use of NTC for relevant research efforts are therefore very encouraging and efforts for this type of activity are recommended. Again, however, the expense and unpredictability of any field study warrants increased planning and preparation to insure multiple and clearly defined avenues for data collection are available to answer research questions. In this way, if one data source results in gaps or unanalyzable data, alternate values can be used to respond to critical questions. The WRAIR sleep pattern data for this study were clearly valid, unquestionably appropriate for the research question be asked and very informative of subject behavior. Unfortunately, random assignment resulted in high and low performing groups having only the subjective performance ratings available for analysis, with no sleep data available. Alternate data or more discrete behavior and performance data would have perhaps provided information which could have led to more definitive analyses, conclusions and modeling utility for these groups.

In summary, the conduct of this study to assess the viability of the use of NTC as a research bed has resulted in a favorable recommendation for further cooperative efforts with NTC. However, the questions to be answered must be well defined, the research plan and data collection items well anchored in behavioral parameters and clear performance measures and procedures must be clearly defined, tested and focused for ease in application and consistency/validity of results.